ISOLATION, TYPICAL WALLS AND ROOF STRUCTURES

1.- INTRODUCTION

- ✓ Buildings are responsible for more than 40% of energy consumption in the EU and responsible for 35% of Greenhouse gas emissions (GHG)

  - ✓ During its useful life: 90 %
  - ✓ Manufacture of materials: 8-10 %
  - ✓ Building process: 2-3 %

- ✓ In order to achieve a better world, technicians are required to minimize the impact of buildings on energy consumption and greenhouse gas emissions:

For example by improving the thermal insulation of the building envelope during the project phase

1.- INTRODUCTION

- ✓ The 2010 Energy Performance of Buildings Directive and the 2012 Energy Efficiency Directive (EED) are the EU's main legislation covering the reduction of the energy consumption of buildings. These key laws are inspired by the **Kyoto Protocol**.
  - EU countries must set minimum energy performance requirements for new buildings, for the major renovation of buildings, and for the replacement or retrofit of building elements (heating and cooling systems, roofs, walls and so on).
  - All new buildings must be nearly **zero energy buildings (nZEB)** by 31 December 2020 (public buildings by 31 December 2018).
  - EU countries must draw-up long-term national building renovation strategies which can be included in their National Energy Efficiency Action Plans.

1.- INTRODUCTION

- ✓ A **zero-energy building** is a building with zero net energy consumption, meaning the total amount of energy used by the building on an annual basis is roughly equal to the amount of renewable energy created on the site or by renewable energy sources elsewhere.
- ✓ The BUILD UP Skills initiative helps train craftsmen, on-site construction workers, and systems installers in the building sector. Its aim is to increase the number of qualified workers across Europe who are able to undertake energy efficient building renovations and help construct nearly zero energy buildings. http://www.buildupskills.eu/
- ✓ The BUILD UP Portal brings together European experts on energy reduction in buildings. The aim is to share information and best practices. http://www.buildup.eu/

1.- INTRODUCTION

- ✓ The development of a harmonized framework of standards for the implementation of DEEE requires the establishment of a calculation methodology.
- ✓ EN 15603:2008 (**Energy performance of buildings - Overall energy use and definition of energy ratings**) introduces calculation procedures and an indicative list of indicators for the assessment of energy efficiency: final energy requirements (constructive quality of the envelope), total primary energy use, total non-renewable primary energy use, and total non-renewable primary energy use considering the impact of exported energy.
- ✓ The standard EN 15603:2008 will be replaced by the standard prEN ISO 52000-1 **[Energy performance of buildings - Overarching EPB assessment - Part 1: General framework and procedures (ISO/FDIS 52000-1:2016)]**

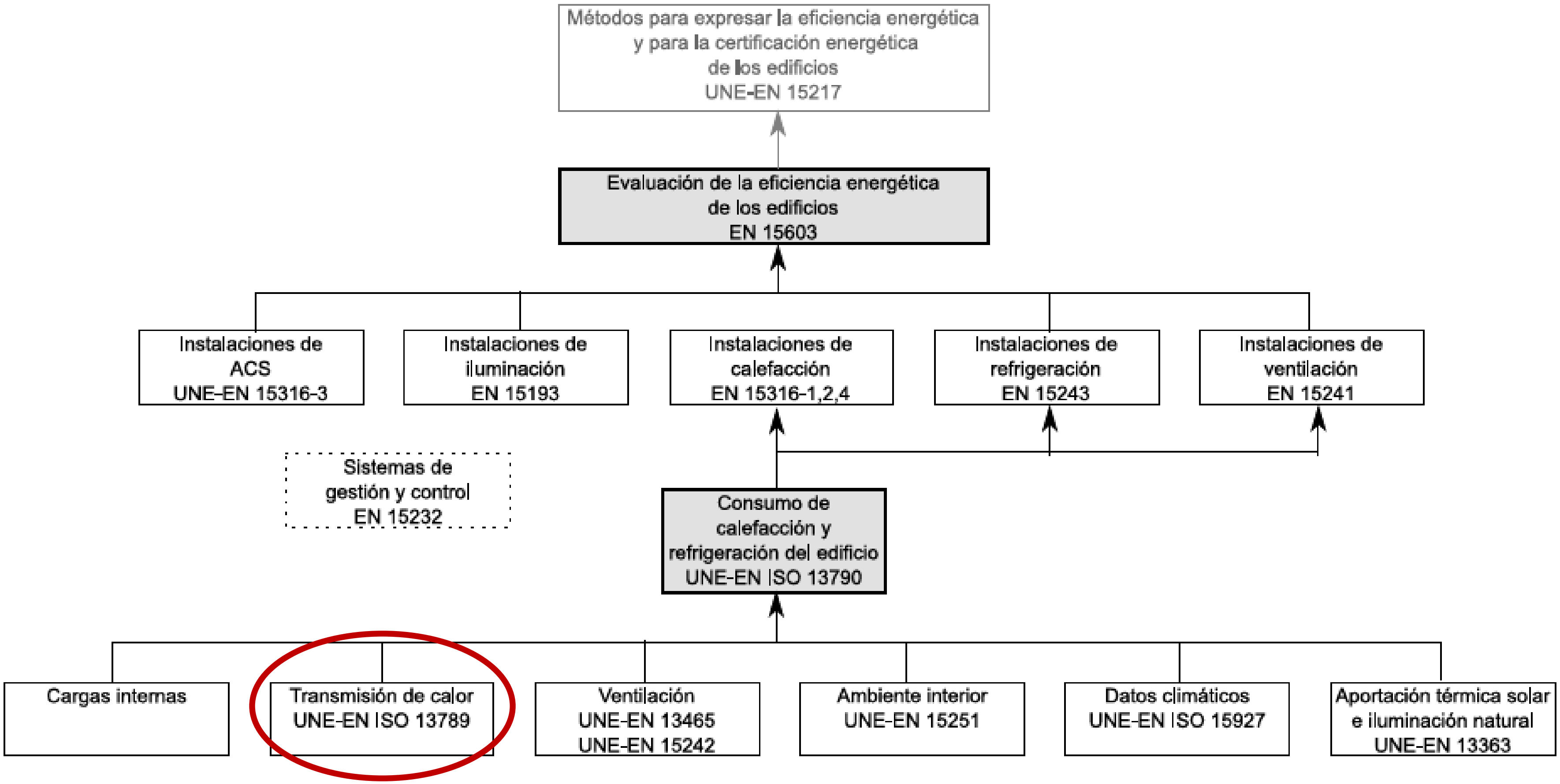


Figura 1: Esquema del marco normativo desarrollado por *CEN/ISO* entorno a la *DEEE*

2.- BUILDING THERMAL ENVELOPE

- ✓ A **building envelope** is the physical separator between the conditioned (interior) and unconditioned (exterior) environment of a building.
- ✓ Walls, floors, roofs, windows and doors are the typical building envelope components.
- ✓ From an energy flow point of view, the envelope is a composition of layers with varying thermal and permeability properties. The **thermal envelope**, or heat flow control layer, is part of a building envelope.
- ✓ The thermal envelope (design and materials) have a high impact on the building's performance (energy consumption and CO_2 emissions).
- ✓ The choice of building thermal envelope is determined by the climate, culture, and available materials.

2.- BUILDING THERMAL ENVELOPE

Heat always flows from hot to cold

The flow of heat through a building envelope varies:

By seasons

In winter: Heat flows goes from inside to outside

In summer: Heat flows goes from outside to inside

The path of the heat (through the materials of a building's skin, or by outdoor air entering)

2.- BUILDING THERMAL ENVELOPE

✓ The design of the thermal envelope should limit the energy requirements of the building.

✓ The **thermal envelope** determines the **passive behavior of the building**. For insulation to be effective it is also important to use proper materials for each part of the building and to install them consistently, avoiding heatbridges

✓ Although **heat transfer** is very important it is not the only important feature of a thermal envelope that affects the envelope efficiency. Three characteristics of a thermal envelope that affect its thermal efficiency most are:

- heat transfer
- phase shift
- water vapor diffusion

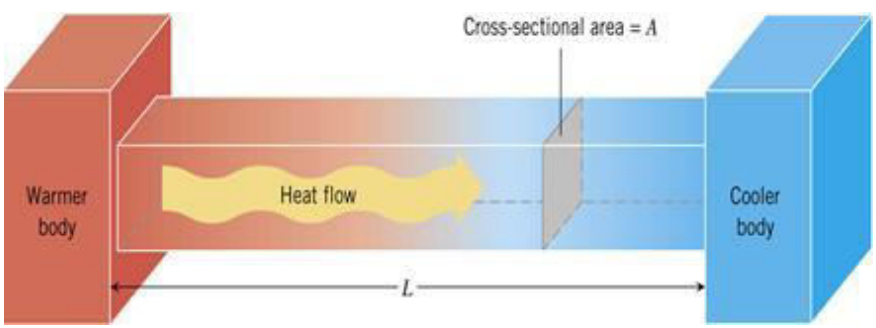
3.- HEAT TRANSFER AND THERMAL PROPERTIES OF BUILDING MATERIALS

- ✓ Heat transfer is the process of thermal exchange between different systems. Generally the net heat transfer between two systems will be **from the hotter system to the cooler** system
- ✓ The main mechanisms of heat transfer in building materials are:
  - Conduction
  - Convection
  - Radiation
- ✓ In engineering contexts, the term heat is taken as synonymous to thermal energy

Poner fotos – esquemas de conducción – convección - radiación

3.1- CONDUCTION

- ✓ **Thermal conduction** is the transfer of heat by microscopic collisions of particles and movement of electrons within a body (atomic vibrations and free electrons in hotter regions transport energy to cooler regions)
- ✓ Conduction takes place in all phases of matter: solids, liquids, gases and plasmas
- ✓ Heat flows from a hotter to a colder body



Conduction is one of the main potential heat transfer mechanisms by which the internal heating or cooling can be lost to the outside, resulting in high operating costs, high carbon emissions and occupant discomfort.

3.1- CONDUCTION

✓ The law of heat conduction in the Fourier's law:

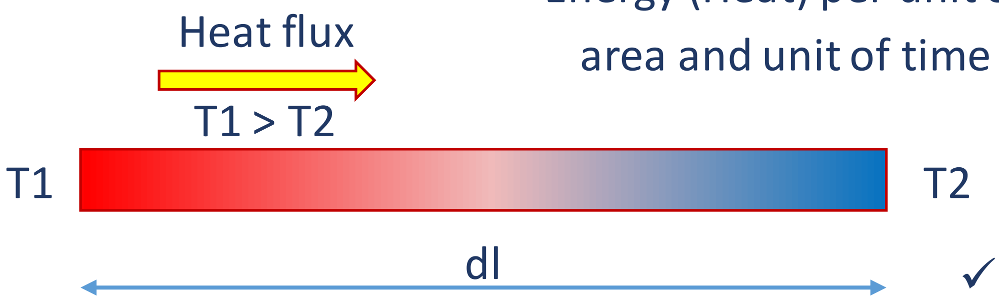
Temperature gradient (ºC)

Heat flux
(J/m²·s; W/m²)

$$\frac{Q_s}{S} = \lambda \frac{dT}{dl}$$

Energy (Heat) per unit of area and unit of time

Thermal conductivity
(W/m·ºK; Kcal/h/m·ºK)



✓ Thermal conductivity is a characteristic property of each building material

✓ The inverse of the **thermal conductivity** is the **thermal resistivity** R (m·ºK/W; m·ºK/ Kcal/h)

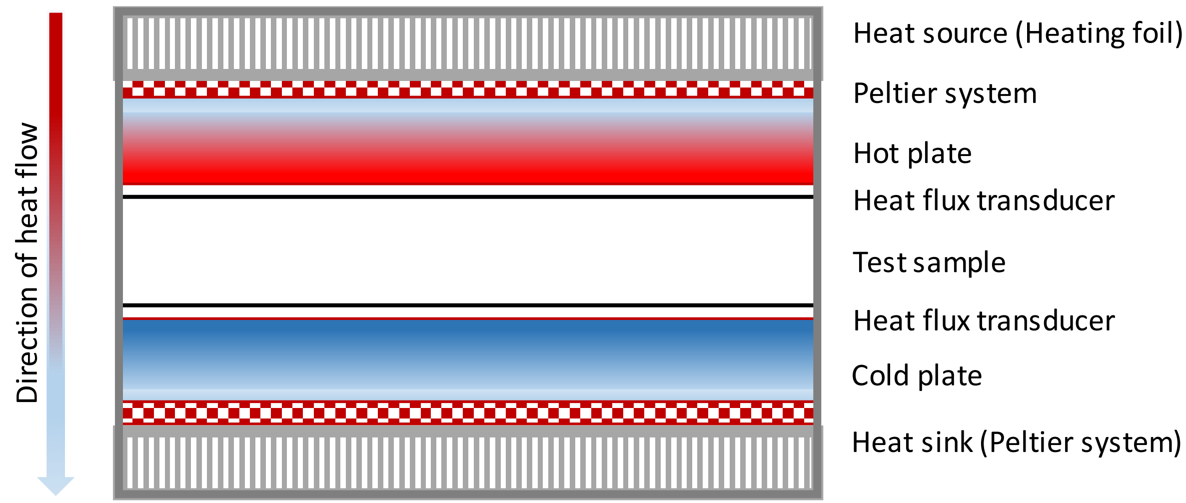
3.1- CONDUCTION

The value of the thermal conductivity of a material is calculated by obtaining the amount of heat (J) passing in the unit of time (s) through a unit of area (m^2) of an infinite spread material with flat and parallel faces of thickness one unit (m), when establishing a difference in temperature between their faces of 1 ºC.

The **thermal conductivity** of the materials is measured with a **Heat Flow Meter**

Range: 0.005 to 0.5 W/m·K

Standard: EN 12667; ISO 8301; ASTM C518



3.1- CONDUCTION

✓ The design values of the thermal conductivity for the majority of building materials can be obtained in the Standard 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)*

In Spain: →

norma española

UNE-EN ISO 10456

Mayo 2012

TÍTULO

Materiales y productos para la edificación

Propiedades higrotérmicas

Valores tabulados de diseño y procedimientos para la determinación de los valores térmicos declarados y de diseño

(ISO 10456:2007)

3.1- CONDUCTION

- This International Standard (EN-ISO 10456:2007) specifies methods for the determination of declared and design thermal values for thermally homogeneous building materials and products, together with procedures to convert values obtained under one set of conditions to those valid for another set of conditions. These procedures are valid for design ambient temperatures between −30 °C and +60 °C.
- This International Standard provides conversion coefficients for temperature and for moisture. These coefficients are valid for mean temperatures between 0 °C and 30 °C.
- This International Standard also provides design data in tabular form for use in heat and moisture transfer calculations, for thermally homogeneous materials and products commonly used in building construction.

Tabulated design hygrothermal values (EN-ISO 10456:2007)

Table 3 gives design values for thermal conductivity, specific heat capacity and water vapour resistance factor for materials commonly used in building applications

Material group or application	Density ρ kg/m^3	Design thermal conductivity λ W/(m·K)	Specific heat capacity c_p J/(kg·K)	Water vapour resistance factor μ	
				dry	wet
Concrete [a]					
Medium density	1 800	1,15	1 000	100	60
	2 000	1,35	1 000	100	60
	2 200	1,65	1 000	120	70
High density	2 400	2,00	1 000	130	80
Reinforced (with 1 % of steel)	2 300	$\boxed{2,3}$	1 000	130	80
Reinforced (with 2 % of steel)	2 400	2,5	1 000	130	80

Tabulated design hygrothermal values (EN-ISO 10456:2007)

Material group or application	Density ρ kg/m^3	Design thermal conductivity λ W/(m·K)	Specific heat capacity c_p J/(kg·K)	Water vapour resistance factor μ	
				dry	wet
Metals					
Aluminium alloys	2 800	160	880	∞	∞
Bronze	8 700	65	380	∞	∞
Brass	8 400	120	380	∞	∞
Copper	8 900	$\boxed{380}$	380	∞	∞
Iron, cast	7 500	50	450	∞	∞
Lead	11 300	35	130	∞	∞
Steel	7 800	50	450	∞	∞
Stainless steel, [b] austenitic or austenitic-ferritic	7 900	17	500	∞	∞
Stainless steel, [b] ferritic or martensitic	7 900	30	460	∞	∞
Zinc	7 200	110	380	∞	∞

Tabulated design hygrothermal values (EN-ISO 10456:2007)

Material group or application	Density ρ kg/m^3	Design thermal conductivity λ W/(m·K)	Specific heat capacity c_p J/(kg·K)	Water vapour resistance factor μ dry	Water vapour resistance factor μ wet
Plastics, solid					
Acrylic	1 050	0,20	1 500	10 000	10 000
Polycarbonates	1 200	0,20	1 200	5 000	5 000
Polytetrafluoroethylene (PTFE)	2 200	0,25	1 000	10 000	10 000
Polyvinylchloride (PVC)	1 390	0,17	900	50 000	50 000
Polymethylmethacrylate (PMMA)	1 180	0,18	1 500	50 000	50 000
Polyacetate	1 410	0,30	1 400	100 000	100 000
Polyamide (nylon)	1 150	0,25	1 600	50 000	50 00
Polyamide 6.6 with 25 % glass fibre	1 450	0,30	1 600	50 000	50 000
Polyethylene /polythene, high density	980	0,50	1 800	100 000	100 000
Polyethylene/polythene, low density	920	0,33	2 200	100 000	100 000
Polystyrene	1 050	0,16	1 300	100 000	100 000
Polypropylene	910	0,22	1 800	10 000	10 000
Polypropylene with 25 % glass fibre	1 200	0,25	1 800	10 000	10 000

Tabulated design hygrothermal values (EN-ISO 10456:2007)

In Spain, the technical code of the Building (https://www.codigotecnico.org/) includes tables with other materials

Morteros				
	HE			
Material	**ρ kg / m³**	**λ W / m·K**	**c_p J / kg·K**	**μ**
Mortero de cemento o cal para albañilería y para revoco o enlucido(1) (2)	ρ >2000	1,80	1000	10
	1800<ρ ≤2000	1,30	1000	10
	1600<ρ ≤1800	1,00	1000	10
	1450<ρ ≤1600	0,80	1000	10
	1250<ρ ≤1450	0,70	1000	10
	1000<ρ ≤1250	0,55	1000	10
	750<ρ ≤1000	0,40	1000	10
	500<ρ ≤750	0,30	1000	10
Mortero de áridos ligeros (vermiculita, perlita) (2)	ρ ≤ 1000	0,41	1000	10
Mortero de yeso	ρ ≤1600	0,80	1000	6

Source: CEC-CTE. Ministerio de Fomento (Spain)

Aislantes térmicos				
	HE			
Material o producto	ρ kg / m^3	λ W / m·K	c_p J / kg·K	μ
Poliestireno Expandido (EPS)	-	0,039(1) – 0,029	-	20 -100
Poliestireno Expandido Elastificado (EEPS)	-	0,046 – 0,029		
Poliestireno Extruído (XPS)				
Expandido con dióxido de carbono CO_2	-	0,039 - 0,033	-	100 - 220
Expandido con hidrofluorcarbonos HFC	-	0,039 - 0,029	-	100 - 220
Lana mineral (MW)	-	0,050 - 0,031	-	1
Espuma rígida de Poliuretano (PUR) o poliisocianurato (PIR)				
Proyección con Hidrofluorcarbono HFC	30 - 60	0,028	-	60 - 150
Proyección con dióxido de carbono CO2 celda cerrada	40 - 60	0,035 - 0,032	-	100 - 150
Plancha con Hidrofluorcarbono HFC o Hidrocarburo (pentano) y revestimiento permeable a los gases.	-	0,030 - 0,027	-	60 - 150
Plancha con Hidrofluorcarbono HFC o Hidrocarburo (pentano) y revestimiento impermeable a los gases.	-	0,025 - 0,024	-	∞

3.1- CONDUCTION

- ✓ Conduction can be inhibited by insulating materials which have a low thermal conductivity and so help reduce heat transfer between the inside and outside
- ✓ An insulating effect can also be achieved by the thermal mass of building components. Thermal mass describes the ability of a material to absorb, store and release heat energy

Poner fotos – materiales aislantes (chapas sandwhich, etc….)

3.2- CONVECTION

- ✓ **Convection** is the transfer of heat from one place to another by the movement of air of different temperatures (convection is the transfer of heat energy by the movement of matter). Convection takes place through advection, difussion or both.
- ✓ **Free or natural convection:** an increase in temperature produces a reduction in density, which in turn causes fluid (air) motion due to pressures and forces when fluids (air) of different densities are affected by gravity (natural ventilation)
- ✓ **Forced convection:** when a fluid (air) is forced to flow over the surface by an internal source such as fans, by stirring, and pumps, creating an artificially induced convection current

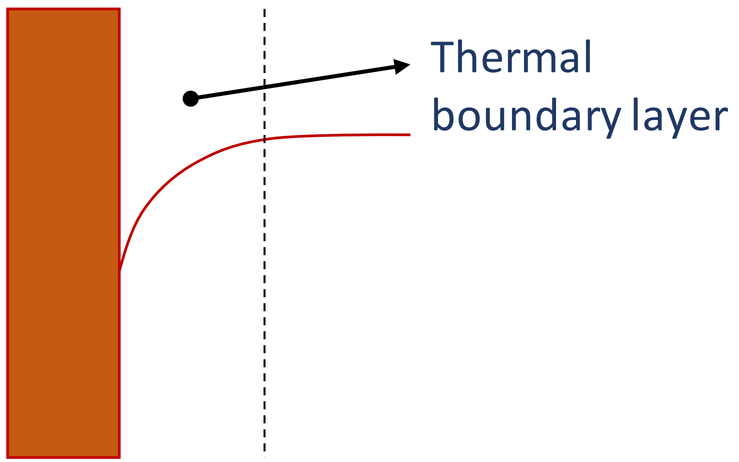
3.2- CONVECTION

- ✓ The velocity of the air is variable within a layer immediately in contact with the walls (**boundary layer**), from a theoretically zero value on the surface of the wall, to a distance in which speed remain constant.
- ✓ The thickness of the boundary layer is difficult to calculate since it depends on the velocity of the air, and on the movement of the air. There are two different types of boundary layer flow: laminar and turbulent.
- ✓ When the fluid regime is turbulent, the heat transfer to the exterior of the wall is increased.
- ✓ if the convection is natural large boundary layers are produced and if it is forced small.

3.2- CONVECTION

- ✓ In the boundary layer a thermal gradient is produced perpendicular to the wall (roof or floor), so we can speak of a thermal boundary layer that does not have to coincide with the boundary speed layer, although it frequently coincides.

- ✓ Its dimension usually varies between 12 and 19 mm, depending on the speed of the air, if the convection is natural large boundary layers are produced and if it is forced small.



Thermal gradient of a temperature limit layer

3.2- CONVECTION

✓ The physical phenomenon of convection heat transfer within the boundary layer can be modeled by Newton's Law of cooling:

Heat transfer coefficient (W/m·ºK; Kcal/h/m·ºK)

Heat flux (J/m²·s; W/m²)

$$\frac{Q_S}{S} = h_C \; dT$$

Temperatures differences (ºK):

The heat-transfer version of **Newton's law** *states that the rate of heat loss of a body is proportional to the difference in temperatures between the body and its surroundings*

Temperature of the object's surface – temperature of the environment

3.2- CONVECTION

The convection coefficient (W/m·ºK) indicates the amount of heat (J) that is transferred in the unit of time (s) by the unit of area (m^2) from a surface in contact with the air towards it when the temperature difference between the surface and the air is 1 °K (or 1ºC).

✓ Convection is a very important mechanism in the design of buildings, where air movement is necessary to:

- Moderate internal temperatures
- Reduce the accumulation of moisture, odors and other gases that can build up during occupied periods
- Improve the comfort of occupants

3.3- RADIATION

- ✓ **Thermal radiation** is electromagnetic radiation generated by the thermal motion of charged particles in matter. All matter with a temperature greater than absolute zero (ºK) emits thermal radiation

- ✓ When the temperature of a body is greater than absolute zero, inter-atomic collisions cause the kinetic energy of the atoms or molecules to change. This results in charge-acceleration and/or dipole oscillation which produces electromagnetic radiation, and the wide spectrum of radiation reflects the wide spectrum of energies and accelerations that occur even at a single temperature

- ✓ Bodies also absorb thermal radiation emitted by their surroundings. The difference in the total amount of radiation emitted and absorbed by a body at any given moment may result in a net heat transfer which will produce a change in the temperature of that body

3.3- RADIATION

- ✓ **Thermal radiation** is one of the principal mechanisms of heat transfer. For conventional constructive situations, where the temperature differences between the bodies exchanging heat are not excessively high, the following expression may be used:

Temperatures differences (ºK)

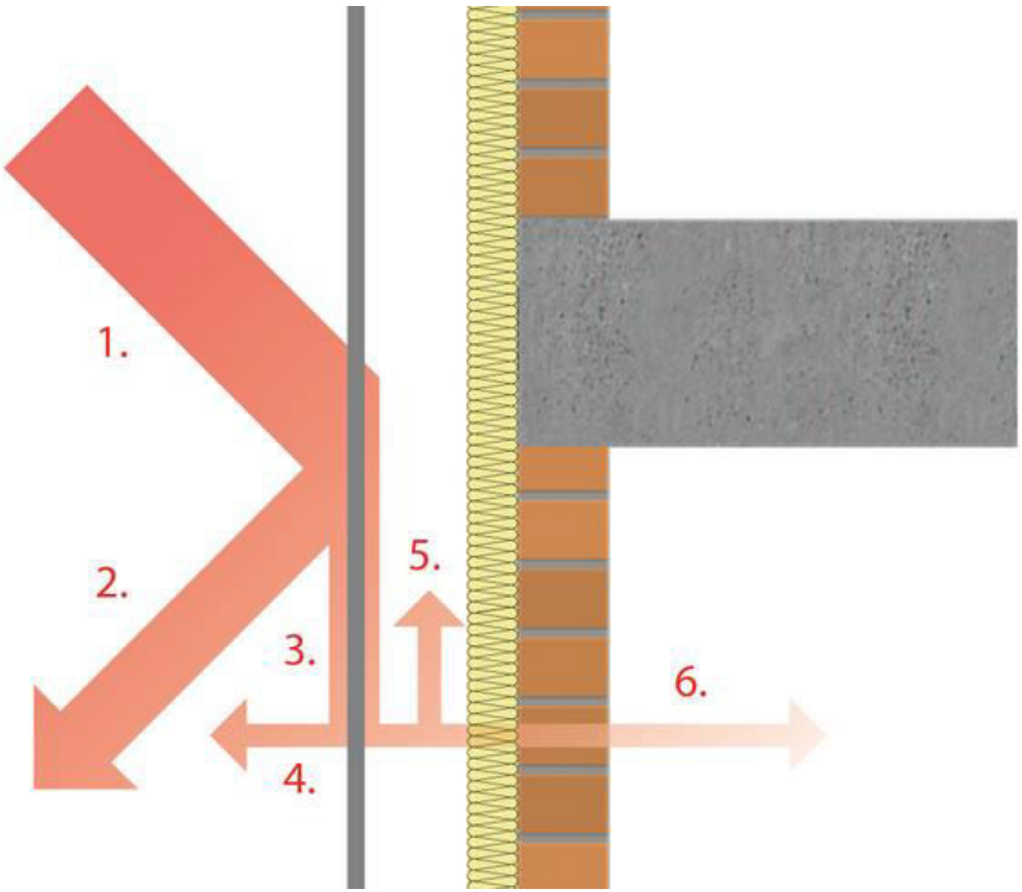
Heat flux (J/m²·s; W/m²)

$$\frac{Q_S}{S} = h_r \; dT$$

Radiation coefficient (W/m·ºK; Kcal/h/m·ºK)

Surfaces in the built environment will tend to absorb solar radiation (short-wave) and emit long wave infra-red radiation

- ✓ For typical building materials, it should not vary considerably from 4.07 W/m² °C



1.- Solar radiation (short-wave)

2.- Reflection

3.- Conduction

4.- Material radiation (long-wave)

5.- Convection

6.- Interior flow

4.- THERMAL TRANSMITTANCE (U) OF THE BUILDING ENVELOPE

4.1- Facade walls, ceilings and floors in contact with the outside air

✓ The **thermal resistance** of a thermally homogeneous layer is defined by the expression:

$$R = \frac{e}{\lambda}$$

Layer thickness (m)

Thermal conductivity (W/m·ºK)

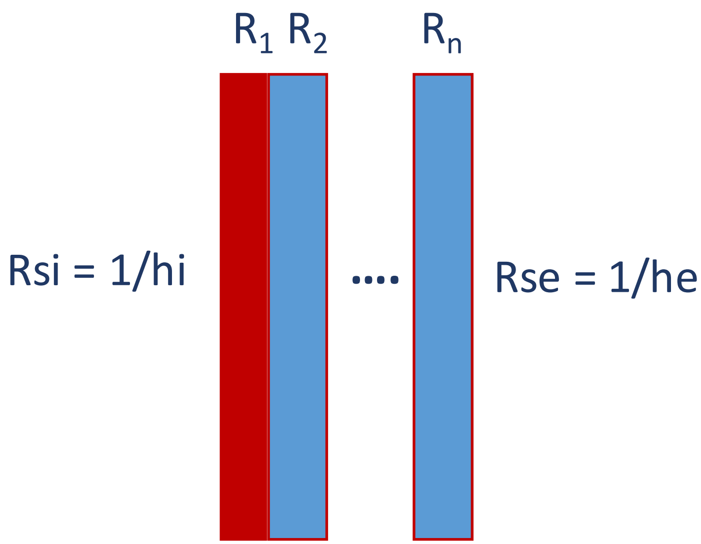
✓ The **thermal transmittance U** (W/m2·ºK) is given by the following expression:

$$U = \frac{1}{R_T}$$

Thermal resistance (m·ºK/W)

4.1- Facade walls, ceilings and floors in contact with the outside air

✓ The **total thermal resistance (RT)** of a component constituted by thermally homogeneous layers is calculated by the expressions:

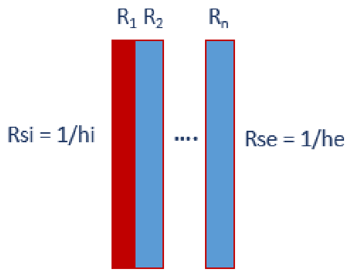


$$R_T = R_{si} + \underbrace{R_1 + R_2 + \ldots + R_n}_{\text{Thermal resistances of each layer of the building envelope}} + R_{se}$$

Thermal resistances for indoor air

Thermal resistances for outdoor air

✓ The **total thermal resistance (RT)** also can be expressed as:



Thickness of the layer

$$R_T = \frac{1}{h_i} + \sum_{1}^{n^{o}\ layers} \frac{e}{\lambda} + \frac{1}{h_e}$$

✓ The inverse of R_T is the **thermal transmittance (U)** of the building component:

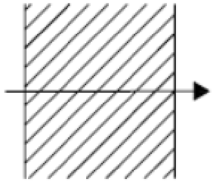
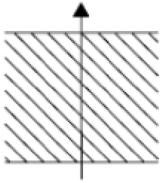
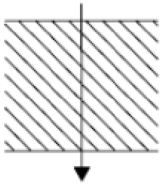
$$U = \frac{1}{R_T} = \frac{1}{\frac{1}{h_i} + \sum_{1}^{n^{\circ}capas} \frac{e}{\lambda} + \frac{1}{h_e}}$$

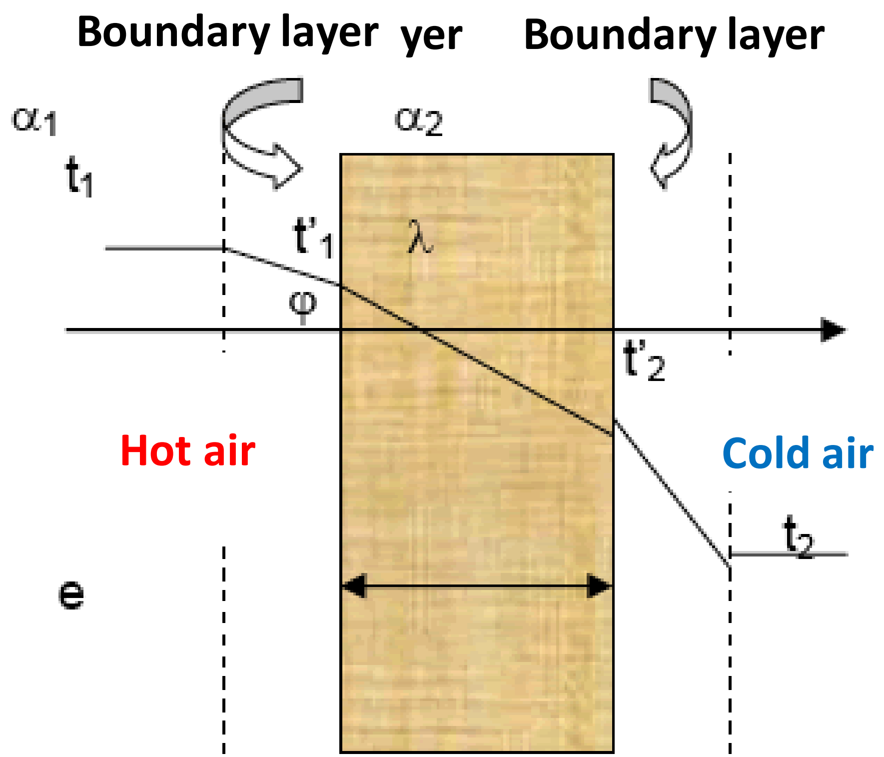
✓ This parameter allows to calculate the flow of heat that crosses a constructive component in permanent regime:

$$Q_C = \sum U \cdot S \cdot (T_i - T_e)$$

Surface **thermal resistances values** (Rse and Rsi) in accordance with the “Documento básico HE: Ahorro de Energía” del Código Técnico de la Edificación (Spain):

Tabla 1 Resistencias térmicas superficiales de cerramientos en contacto con el aire exterior en $m^2 \cdot K/W$

Posición del cerramiento y sentido del flujo de calor		R_{se}	R_{si}
Cerramientos verticales o con pendiente sobre la horizontal >60° y flujo Horizontal		0,04	0,13
Cerramientos horizontales o con pendiente sobre la horizontal ≤60° y flujo ascendente (Techo)		0,04	0,10
Cerramientos horizontales y flujo descendente (Suelo)		0,04	0,17



- The **Rsi and Rse** values are the result of the combined effects of **convective and radiant** heat transfer.
- The value of the heat transfer surface coefficient (h) is the sum of the convection coefficient (hc) and the radiation coefficient (hr). It takes two values: (hi) for the indoor environment and (he) for the outdoor environment

$$h = h_c + h_r$$

$$R_{si} = 1/h_i \ (m^2 K/W)$$

$$R_{se} = 1/h_e \ (m^2 K/W)$$

- If there is a physical discontinuity created by an **air chamber**, it is necessary to add to the set of resistances the own of this element.

- In an air chamber there are no conductive heat transmissions (except edge elements), but there is heat transfer by convection and by radiation, since the two faces that delimit the chamber are at a different temperature.

- The most important component is convective, it can be optimized taking into account that the boundary layers imply a thermal gradient, indicating that these layers are offering a resistance to heat flow. Therefore, in order to obtain the maximum resistance, the thickness of the air chamber must be approx. Twice the thickness of a boundary layer (between 2.4 and 3.8 cm).

✓ According to the CTE, In Spain, the air chambers can be characterized by their thermal resistance, according to the following typologies:

- ❑ Non-ventilated air chamber:

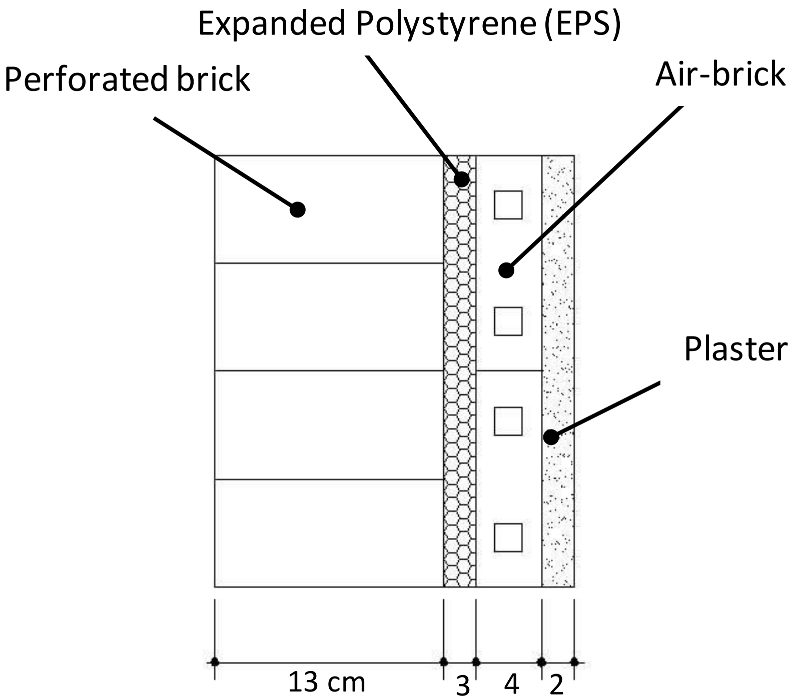
Tabla 2 Resistencias térmicas de cámaras de aire en $m^2 \cdot K/W$

e (cm)	Sin ventilar	
	horizontal	vertical
1	0,15	0,15
2	0,16	0,17
5	0,16	0,18

- ❑ Lightly ventilated air chamber: The thermal resistance is half of the values in Table 2.

- ❑ Ventilated air chamber: the total thermal resistance of the enclosure is obtained by neglecting the thermal resistance of the air chamber and those of the other layers between the air chamber and the external environment, and including an Rse = Rsi

4.1- Facade walls, ceilings and floors in contact with the outside air (Example):



- Perforated brick
- 13 cm thick

→ $R_1 = 0.21\ m^2\ ºK/W$

- Expanded Polystyrene (EPS)

$$R_2 = \frac{e}{\lambda} = \frac{0.03\ m}{0.039} = 0.769\ m^2\ {}^\circ K/W$$

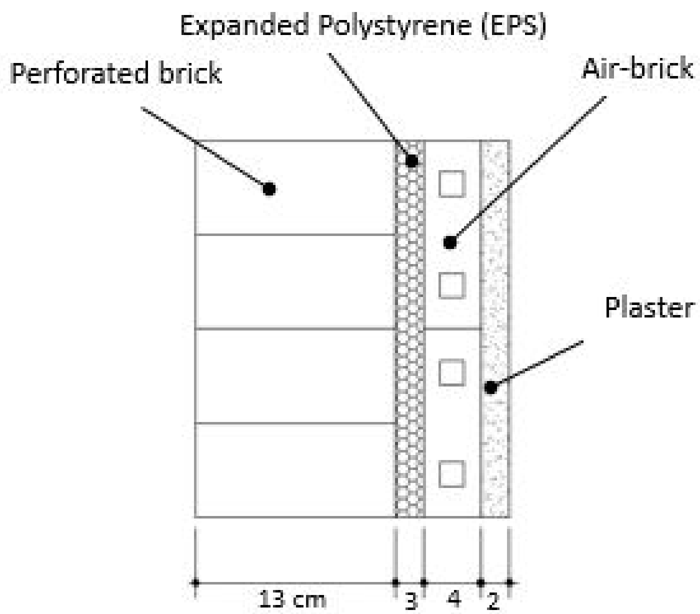
- Air-brick
- 4 cm thick

→ $R_3 = 0.09\ m^2\ ºK/W$

- Plaster → $\lambda = 0.4\ W/m\ ºK$

$$R_4 = \frac{e}{\lambda} = \frac{0.02\ m}{0.4} = 0.05\ m^2\ {}^\circ K/W$$

Data from: *Documento Basico HE-1 Ahorro de Energia del CTE (Spain)*

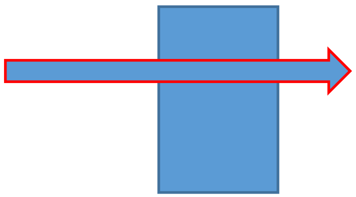


4.1- Facade walls, ceilings and floors in contact with the outside air (Example):

- Surface thermal resistances values (Rse and Rsi)

$R_{se} = 0.04$ m² ºK/W

$R_{si} = 0.13$ m² ºK/W



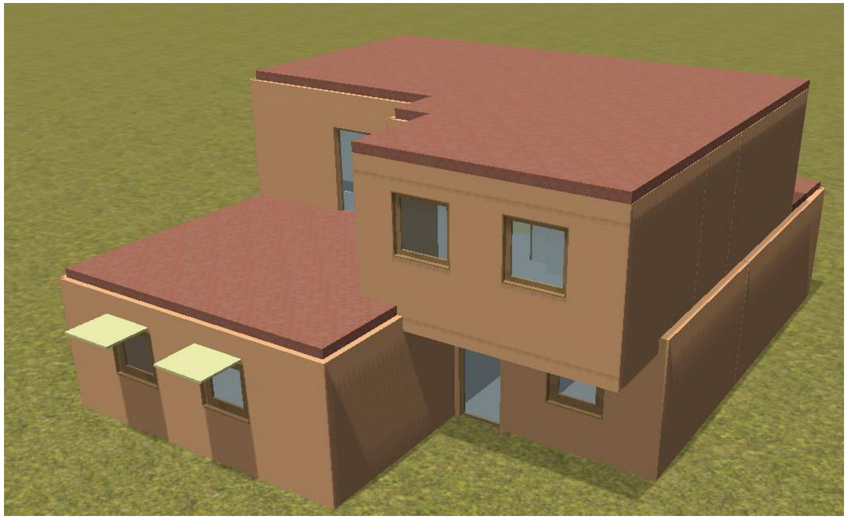
$$R_T = R_{se} + R_1 + R_2 + R_3 + R_4 + R_{si} = 0.04 + 0.21 + 0.769 + 0.09 + 0.05 + 0.13 = 1.289 \text{ m}^2\,\text{ºK/W}$$

$$U_M = \frac{1}{R_T} = \frac{1}{1.289} = 0.78 \text{ W/m}^2\cdot\text{ºK}$$

6.- IMPORTANCE OF THE BUILDING ENVELOPE

- ✓ In order to limit the energy consumption of a building, special attention must be paid to the design of the building envelope, ensuring the maintenance of the thermal performance over time, and avoiding decompensation in the thermal quality of the spaces and units of use.

- ✓ Different indicators and calculation procedures defined in EN ISO 13790: 2008 can be used to measure the quality of the building's thermal envelope. The most important are K (global thermal transmittance) and Qsol; jul (solar gains).



6.- IMPORTANCE OF THE BUILDING ENVELOPE

- ✓ The objective of the global thermal transmittance (K) indicator is to ensure the efficiency of the thermal envelope in relation to the heat transfer, taking into account the protected habitable volume and its heat exchange surface with the exterior.
- ✓ This indicator integrates the characteristics of the elements that configure the thermal envelope, its proportion, the care of the thermal bridges and modulates its demand as a function of the external climate and the compactness of the thermal envelope (V/A).
- ✓ The indicator is calculated from the transmission heat transfer coefficient, described in EN ISO 13790: 2008, and the heat exchange area of the envelope ($\Sigma_i A_i$).

EN ISO 13790:2008

Energy performance of building. Calculation of energy use for space heating and cooling.

6.- IMPORTANCE OF THE BUILDING ENVELOPE - Opaque enclosures

1.- The geometric characteristics of the enclosures of living and non-habitable spaces, as well as of interior partitions, which are in contact with the air or the terrain or are considered adiabatic for calculation purposes, should be defined.

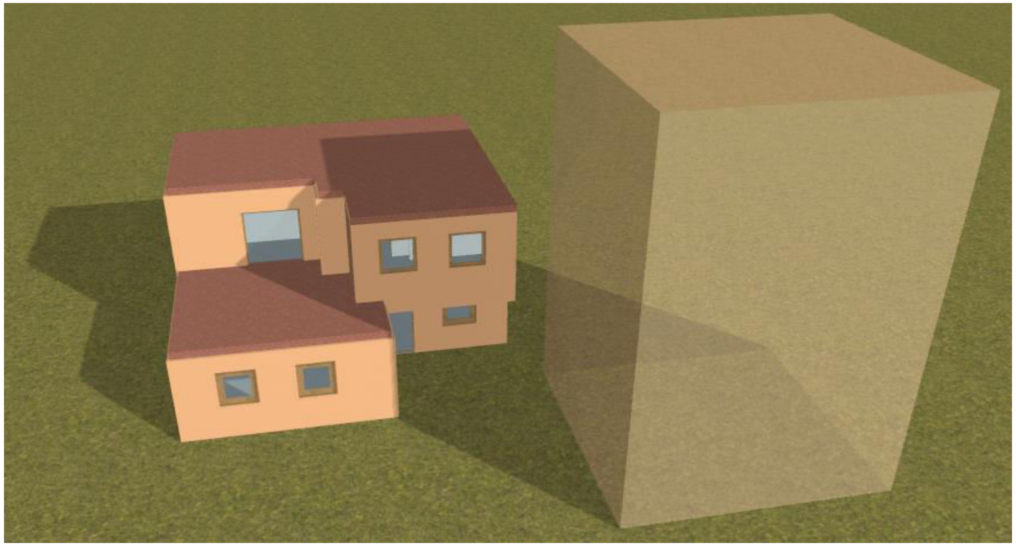
2.- The parameters of the enclosures that adequately describe their thermal performance should be defined. A simplified description may be used by aggregation of parallel and homogeneous layers having equivalent thermal behavior.

3.- The thickness, density, conductivity and specific heat of the layers with appreciable thermal mass must be defined. In the case of layers without significant thermal mass (air chambers) their properties can be described through the total resistance of the layer and its thickness.

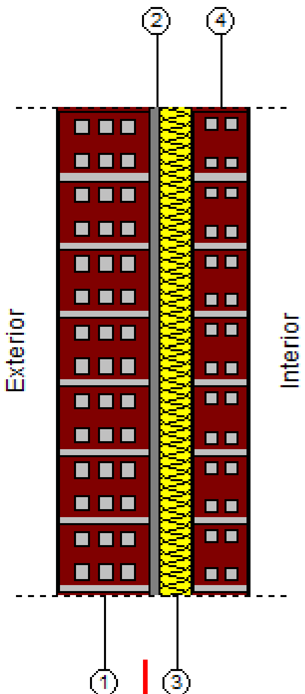
6.- IMPORTANCE OF THE BUILDING ENVELOPE - Opaque enclosures

4.- Shadows cast by remote obstacles on the outer walls of the building must be taken into account.

5.- The air permeability of opaque enclosures and the effect of grilles and aerators must be taken into account (if applicable).

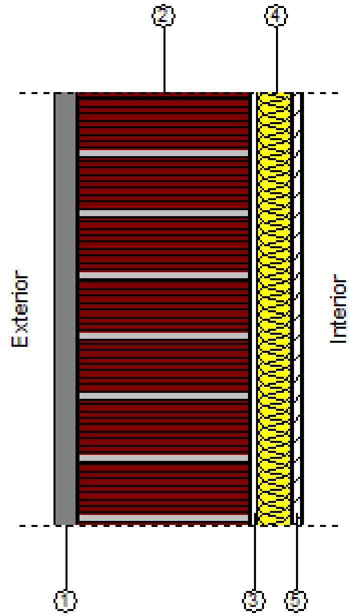


Example of shading of a nearby building on the building under study



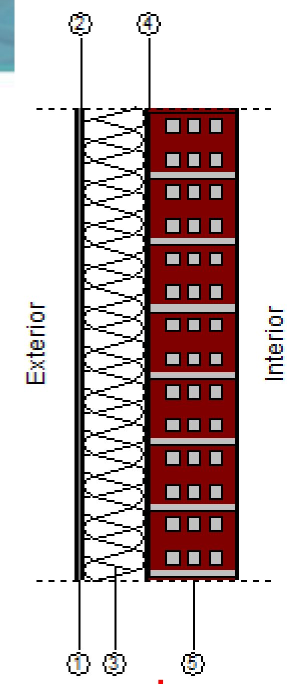
$U_m = 0{,}6\ W/(m^2\ K)$

1 - Fábrica de ladrillo cerámico perforado cara vista: 11.5 cm
2 - Enfoscado de cemento a buena vista: 1 cm
3 - Lana mineral: 4 cm
4 - Fábrica de ladrillo cerámico hueco: 7 cm
Espesor total: 23.5 cm



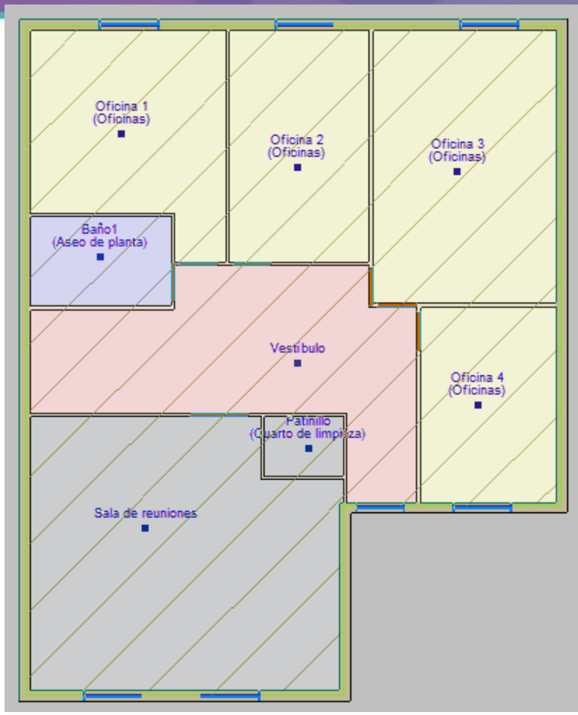
1 - Chapado con placas de mármol Amarillo Marés "LEVANTINA": 3 cm
2 - Fábrica de bloque de termoarcilla: 24 cm
3 - Separación: 1.3 cm
4 - Lana mineral: 4.5 cm
5 - Placa de yeso laminado: 1.5 cm
Espesor total: 34.3 cm

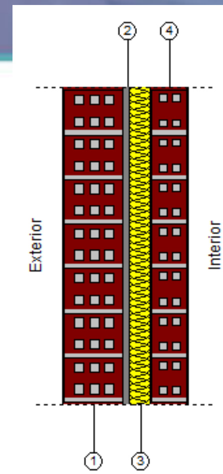
$U_m = 0{,}45\ W/(m^2\ K)$



1 - Mortero decorativo Weber.pral Clima "WEBER CEMARKSA": 0.3 cm
2 - Mortero base Weber.therm Base "WEBER CEMARKSA": 0.5 cm
3 - Panel rígido de lana de roca Isofex "ISOVER": 8 cm
4 - Mortero base Weber.therm Base "WEBER CEMARKSA": 0.5 cm
5 - Fábrica de ladrillo cerámico hueco: 11 cm
Espesor total: 20.3 cm

$U_m = 0{,}38\ W/(m^2\ K)$





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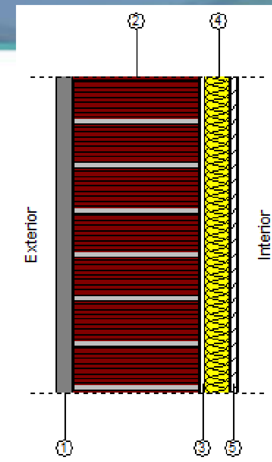

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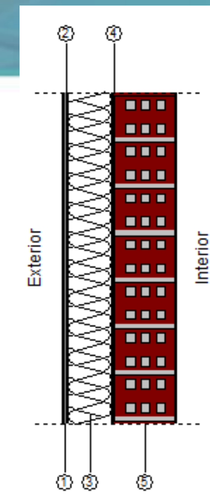


3

RESULTS OF THE CALCULATION OF ENERGY DEMAND

Percentage of saving of the energy demand with respect to the reference building

1 $\%_{AD} = 100 \cdot (D_{G,ref} - D_{G,obj}) / D_{G,ref} = 100 \cdot (44.2 - 37.0) / 44.2 = \mathbf{16.3\ \%} \geq \%_{AD,exigido} = \mathbf{25.0\ \%}$

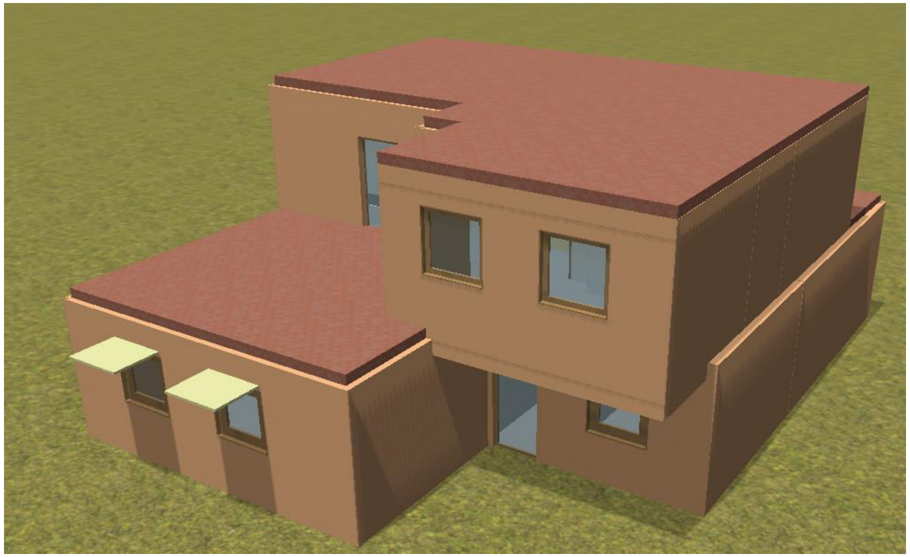
2 $\%_{AD} = 100 \cdot (D_{G,ref} - D_{G,obj}) / D_{G,ref} = 100 \cdot (44.6 - 34.6) / 44.6 = \mathbf{22.5\ \%} \geq \%_{AD,exigido} = \mathbf{25.0\ \%}$

3 $\%_{AD} = 100 \cdot (D_{G,ref} - D_{G,obj}) / D_{G,ref} = 100 \cdot (43.7 - 32.4) / 43.7 = \mathbf{25.9\ \%} \geq \%_{AD,exigido} = \mathbf{25.0\ \%}$

6.- IMPORTANCE OF THE BUILDING ENVELOPE – Holes and Gaps

1.- The geometrical characteristics of the holes and the space to which they belong should be considered, as well as the solar protections, whether fixed or mobile, and other elements that can produce shadows or reduce the solar reception of the gaps.

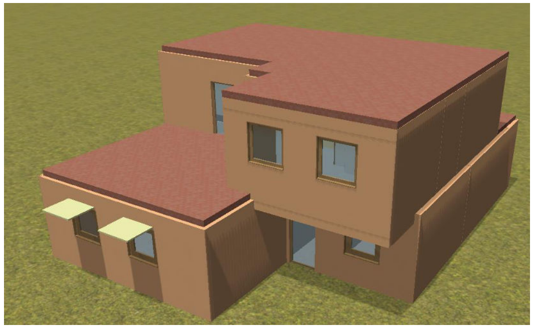
2.- For hollows (windows or door), it is necessary to define the thermal transmittance of the glass and the frame, the surface of both, the solar factor of the glass and the absorptivity of the outer face of the frame.



6.- IMPORTANCE OF THE BUILDING ENVELOPE – Holes and Gaps

3.- In the case of doors whose semi-transparent surface is less than 50%, it is necessary to consider only the thermal transmittance and, where necessary, the absorptivity.

Solar factor ($g^{\perp}$): quotient between solar radiation at normal incidence that is introduced into the building through the glazing and what would be introduced if the glazing was replaced by a perfectly transparent recess. It refers exclusively to the semi-transparent part of a gap.

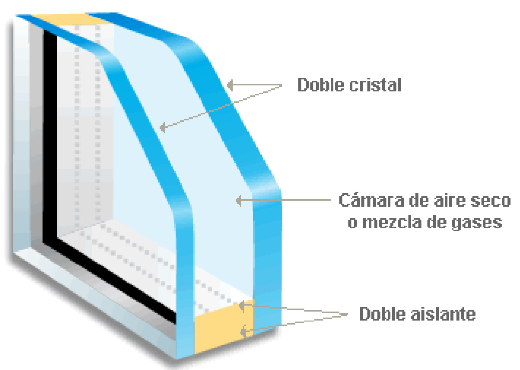


Absorptivity (α): fraction of the incident solar radiation to a surface that is absorbed by that surface. Absorbance ranges from 0.0 (0%) to 1.0 (100%).

6.- IMPORTANCE OF THE BUILDING ENVELOPE – Holes and Gaps

4.- The air permeability of the voids should be considered for the glass frame assembly including the effect of ventilation aerators (if necessary).

The air permeability limits correspond to the void classifications established in EN 12207: class 1 (≤50 m^3 / $h \cdot m^2$) and class 2 (≤27 m^3 / $h \cdot m^2$). The permeability of the indicated carpentries is the measurement with an overpressure of 100 Pa.



(•) Incoloro ( ) Color

Información técnica

Transmitancia térmica (valor U), según UNE-EN 673: 3.3 W/(m²K)

Factor solar (coeficiente g), según UNE-EN 410: 77%

Transmisión luminosa, según UNE-EN 410: 81%

Índice de aislamiento a ruido aéreo directo, Rw (dB) y términos de adaptación espectral C y Ctr, según UNE-EN 12758: 28 (-1; -3)

(•) AISLAGLAS "Doble acristalamiento"

Vidrio exterior: (•) Float incoloro ( ) Impreso Clarglas
Espesor (mm): (•) 4 ( ) 5 ( ) 6 ( ) 8 ( ) 10 ( ) 12

Cámara: (•) Aire ( ) Gas argón
Espesor de la cámara (mm): (•) 6 ( ) 8 ( ) 10 ( ) 12 ( ) 14 ( ) 16 ( ) 18 ( ) 20

Vidrio interior: (•) Float incoloro ( ) Impreso Clarglas
Espesor (mm): (•) 4 ( ) 5 ( ) 6 ( ) 8 ( ) 10 ( ) 12

Chamber thickness	U W/(m²K)
8	3,1
10	3,0
12	2,9
14	2,8
16	2,7
18	2,7
20	2,8

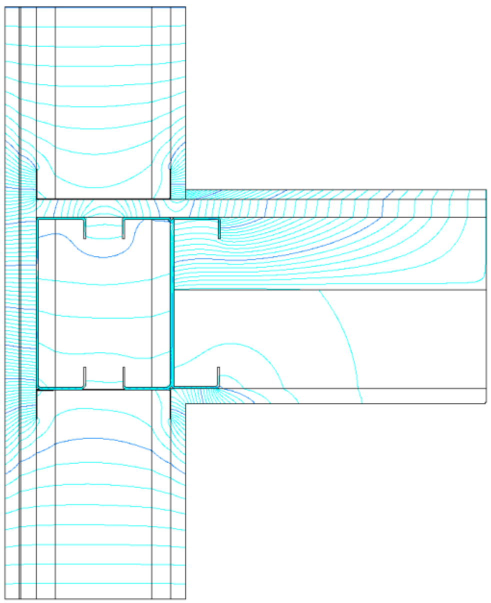
Optimal chamber thickness = 16 mm → **Solution 4+16+4**

6.- IMPORTANCE OF THE BUILDING ENVELOPE – Thermal bridges

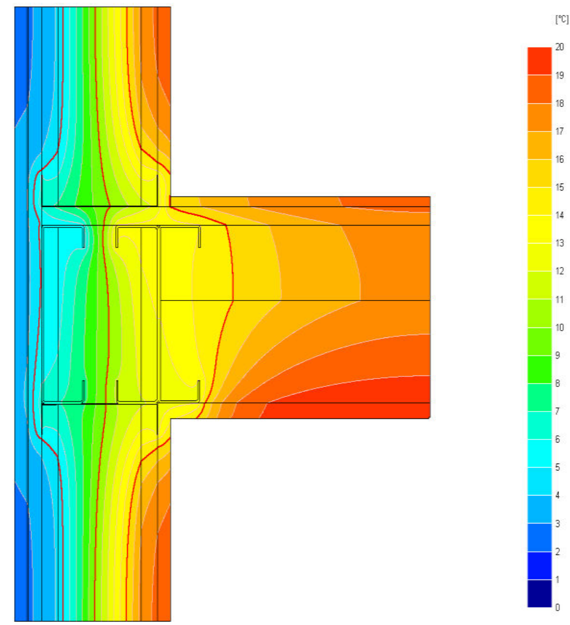
1.- The linear thermal bridges of the building should be considered. The thermal bridges should be characterized by their type, length and the linear thermal transmittance obtained in relation to the contiguous enclosures..

An adequate design of the constructive solutions of the building from the point of view of its thermal performance requires a careful analysis of the presence of thermal bridges. As far as possible, thermal bridges should be avoided, since in thermal insulated buildings a significant part of thermal energy is lost by thermal bridges and in addition they are areas where the risk of condensation increases.

Linear thermal bridge



Thermal Flow Lines

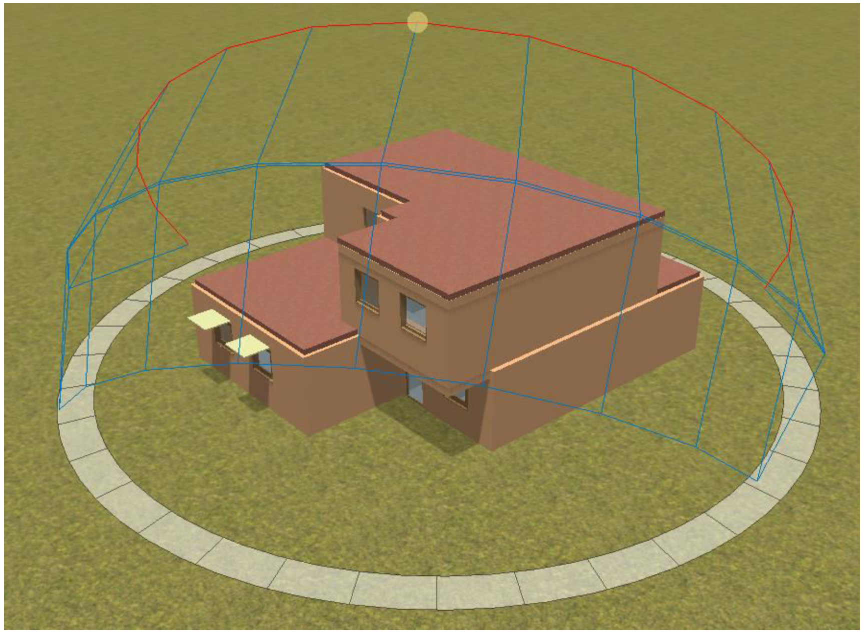


Isotermas

Linear thermal transmittance (EN ISO 10211-2)

psi = Q/(ti-te) - U1*l1 - U2*l2 = 0.449 W/(m.K)

6.- IMPORTANCE OF THE BUILDING ENVELOPE – Solar control



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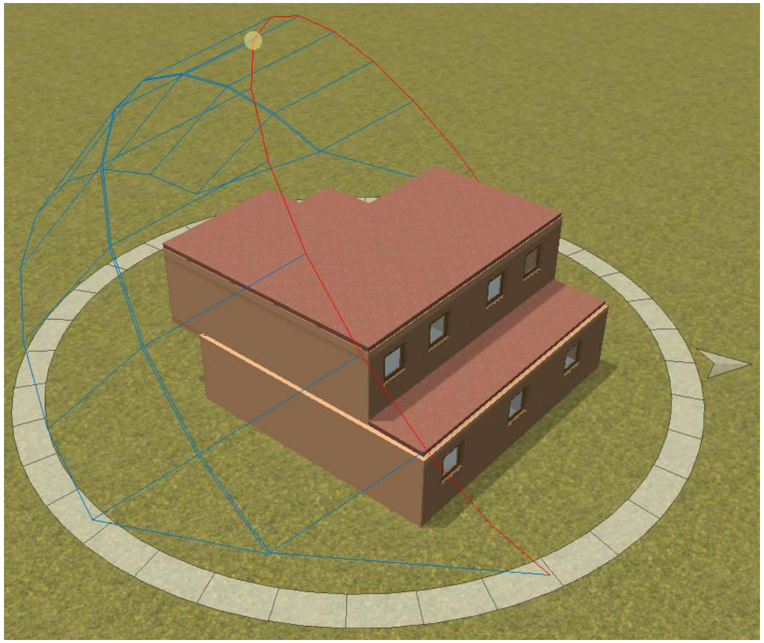
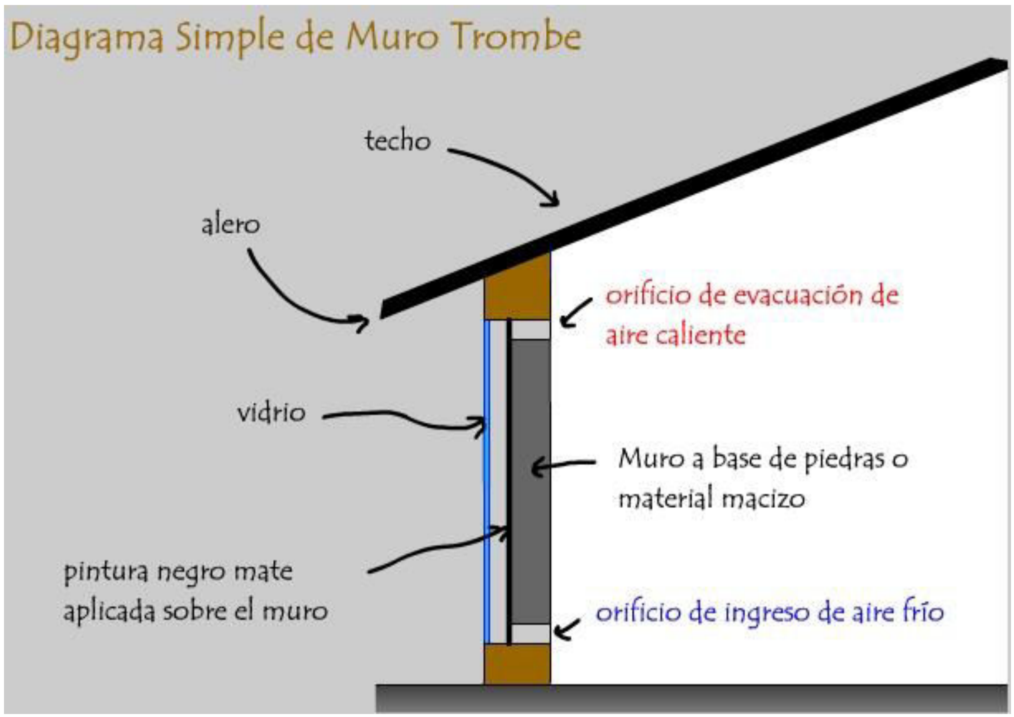
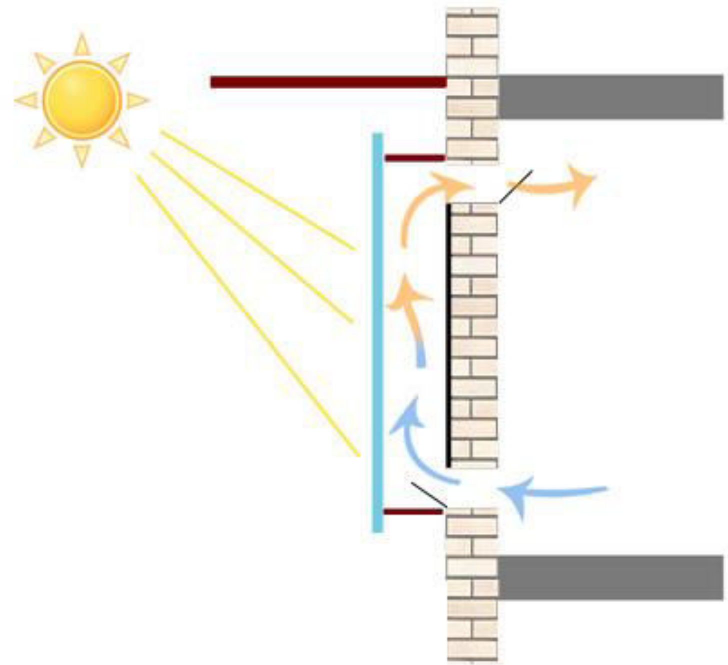


Passive energy saving systems

Muro Trombe.





References:

1. Directive 2012/27/eu of the european parliament and of the council. October 2012.
2. Directive 2010/31/eu of the european parliament and of the council. May 2010.
3. Documento Básico de Ahorro de Energía. DB-HE 2013. Ministerio de Fomento (Spain).
4. Aplicación de la Directiva de eficiencia energética — Orientaciones de la Comisión. Bruselas 2013. COM(2013) 762 final.
5. EN-10456:2007. *(Building materials and products. Higrotermal propierties. Tabulated desing values and procedures for determining declared and desing thermal values.)*
6. EN 15603:2008*. (Energy performance of buildings - Overall energy use and definition of energy ratings).*
7. Catálogo de Elementos Constructivos del CTE. Ministerio de Fomento (Spain). 2011.

References:

8. UNE-EN ISO 13789:2010. *(Thermal performance of buildings - Transmission and ventilation heat transfer coefficients - Calculation method (ISO 13789:2007))*
9. UNE-EN ISO 13790:2011. *(Energy performance of buildings - Calculation of energy use for space heating and cooling (ISO 13790:2008)).*
10. UNE-EN ISO 8996:2005. *(Ergonomics of the thermal environment - Determination of metabolic rate (ISO 8996:2004)).*
11. *Cype Ingenieros. Módulo Cypecad Mep. 2017.*
12. *Las técnicas de acondicionamiento ambiental: Fundamentos arquitectónicos. César Bedoya Frutos; Fco. Javier Neila. UPM. 1992.*

José Antonio Entrenas Angulo

José Ramón Jiménez Romero

University of Córdoba

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