Datasheet III.5.1

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THERMAL ASSESSMENT OF A MIXED BUILDING TECHNOLOGY SOLUTION

Introduction

- Thermal comfort can be defined has a state where a person does not feel any sensation of unpleasantness or irritation that can distract him from his activities in that moment. However, since this state of comfort is the result of different sensations, where many subjective factors interfere, this state won't be easy to define.
- In the design phase there are some climatic actions to consider in order to obtain a state of thermal comfort:
    - exterior temperature;
    - solar radiation;
    - wind.
- Buildings are systems that closely interact with their surrounding environment but some twentieth century buildings deny that interaction and their thermal comfort is obtained by the application of expensive heating, cooling and lightning equipments. In order to avoid this excessive energy consumption and maintain the thermal comfort standards, the buildings must be designed in a way that they can respond to the environment by the intelligent use of materials and a minimal reliance on machinery, as observed in Figure 1 and Figure 2 (Goulding, 1993).

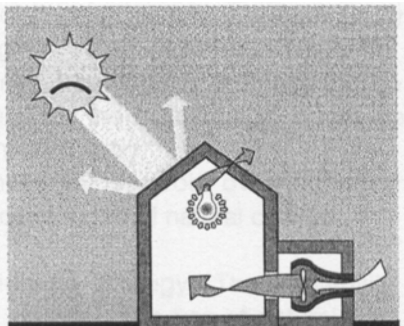

Figure 1. Design without regarding the surrounding environment

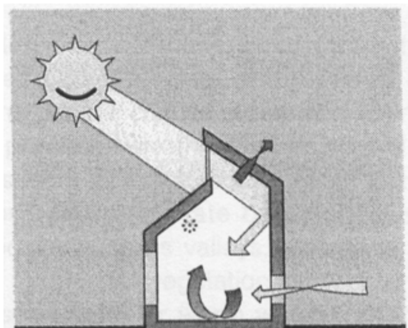

Figure 2. Design regarding the surrounding environment

Thermal Performance

The buildings thermal performance can be characterized by the balance between the heat losses and heat gains taking into account their heat storage capacity. In this balance the three fundamental parameters are the insulation level, thermal inertia use and solar radiation control.

Heat Losses

The heat losses can occur by conduction through the external surfaces, infiltration and ventilation. Heat losses can be controlled with the application of insulation in the external envelope as well as controlling the air infiltration rates and the ventilation mechanisms.

- **Insulation**

The insulation level of the external envelope is related to the resistance that this construction element offers to the heat flow (Figure 3). The following expression gives the heat flow through one element:

$$Q = U \cdot S \cdot (\theta_i - \theta_e) \quad (1)$$

Where:

U – overall heat transfer coefficient (W/m^2.ºC);
S – surface area of the element (m^2);
θ_i – interior air temperature (ºC);
θ_e - exterior air temperature (ºC).

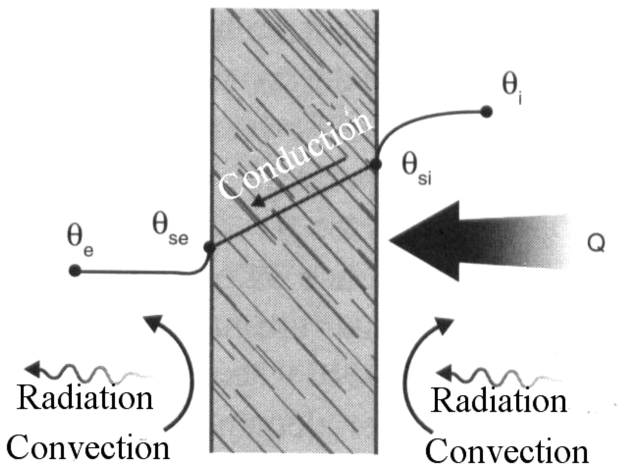

Figure 3. Thermal transmission

A side-effect of the use of insulation in the external envelope is the increase of the superficial temperature of the envelope. This increase results in a higher mean radiant temperature, which increase the comfort level. The most effective mean of increasing this comfort level by this side-effect is the use of low-U glazing.

With the increase of insulation one must be very careful in order to avoid thermal bridges (points with higher U-values). One measure used to avoid thermal brides is the application of continuous thermal insulation on the exterior façade of the building.

- **Infiltration and Ventilation**

In order to maintain a healthy environment inside buildings it's needed a certain amount of fresh air. To control the heat losses by infiltration and ventilation there are many points that must be controlled:

- Type of ventilation - natural or mechanical;
- Air flow through openings and cracks in the external envelope;
- Infiltration - the rate of air infiltration in a house depends of the wind velocity,

pulsation effects or temperature differences;

- Occupants use of doors and windows.

Heat Storage

The heat storage his controlled by the thermal inertia of the building elements. To increase the heat storage, the envelope material must be heavyweight and with high thermal diffusivity.

- **Thermal inertia**

Thermal inertia is responsible for the reduction of inside air temperature peaks and for the delay between the accumulation of energy and its respective release. Then, the thermal inertia can be very useful in winter because the accumulation of heat occurs when there is solar radiation and therefore the heat is less needed. The release of heat, due to the delay, occurs only at night when it is most needed (Figure 4 and Figure 5).

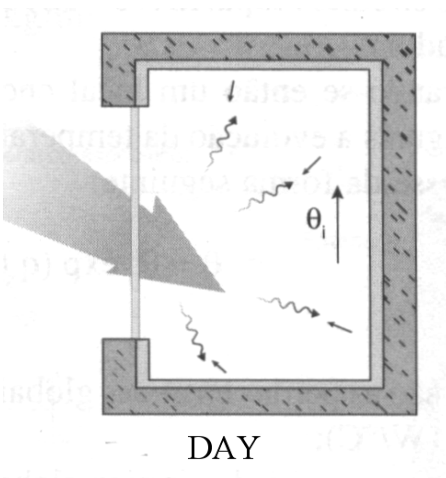

Figure 4. Accumulation of the energy

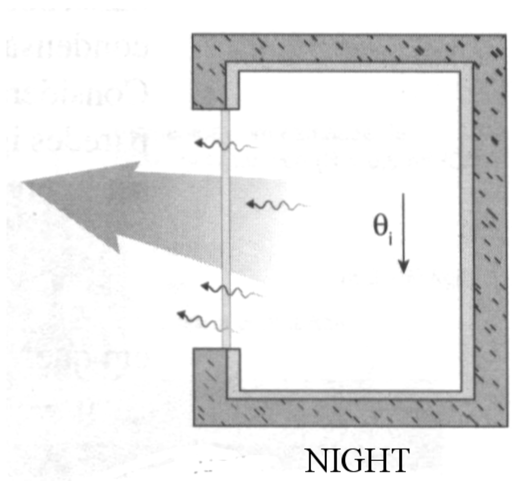

Figure 5. Realese of the energy

Heat Gains

Heat gains can be obtained either by solar radiation or by internal gains.

- **Solar Radiation**

In order to obtain heat gains by solar radiation there must exists a great area of south oriented windows. But, to convert the solar radiation into useful heat gains, the building must also possesses thermal inertia.

In Southern countries, it is also necessary to take care with excessive solar gains, which are responsible for frequent overheating situations, making mandatory the use of shading devices in all windows. Solar radiation is an essential source of heat gains that can balance the heat losses but its use and control must be carefully thought and defined since the very beginning of the project, in the design phase.

- **Internal gains**

Internal heat gains are other kind of gains that can occur inside buildings that are related with the normal use of the habitation (Achard, 1989):

1. heat supply from occupants;
2. heat supply from artificial lightning;
3. heat gains due to appliances.

Thermal Performance Evaluation

- There are many ways to evaluate the thermal performance of buildings. The method used was the one recommended by the EN ISO 13790: 2003. This method was based on the determination of the anual energy needs.
- This quantification was based on the thermal load concept defined as the calorific power required to be supplied to (in Winter) or to be removed from a space (in Summer) so that the comfort conditions, such as the temperature (20ºC in the heating season and 25ºC and 50% relative humidity in the cooling season), remain constant.
- The thermal load is obtained from the energy balance of the space under consideration. Four separate components are found in this balance:
    - Heat exchange by conduction through the opaque envelope, comprising roofs, floors and walls;
    - Heat exchange by solar radiation and by conduction through glazed areas;
    - Heat exchange associated with the indoor air renewal, which can be caused by forced ventilation, natural ventilation or by infiltration;
    - Heat released by internal heat sources, such as equipment, lighting and occupants;
- The annual heating needs (HN) result from the algebraic sum of three components integrated for the heating season divided by the useful floor area (A_p):
    - Heat loss by conduction through the external envelope, taking also in consideration the losses through elements in contact with the ground and losses through thermal bridges, Q_t;
    - Heat loss associated with the indoor air renewal, Q_v;
    - Heat gains by internal heat sources and by solar radiation, Q_{gu}.

$$HN = \left(Q_t + Q_v - Q_{gu}\right)/\mathrm{A_p} \tag{2}$$

- The methodology used to calculate the annual cooling needs (CN) it's complementary to the one used for the annual heating needs and are calculated by the following equation:

$$CN = Q_g \cdot \left(1-\eta\right)/\ A_p \tag{3}$$

Where:

Q_g – are the building total gains;

η - is the factor of gains use;

- The building total gains are given by integrating the algebraic sum of the following portions, for the cooling season:
    - Heat gains by conduction through the outer envelope, Q_1;
    - Solar heat gains through glazed areas, Q_2;
    - Heat gains through indoor air renewal, Q_3;
    - Heat gains from indoor heat sources, Q_4.

Guidelines and/or codification

- Directive 2002/91/CE of the European Parliament of 16 December 2002 –*Thermal Performance of Buildings.*
- EN ISO 13790: 2003 - Thermal performance of buildings - *Calculation of energy use for space heating.*

Example of application: The thermal performance of a MBT building

- Building description

  MBT buildings combine different structural construction methods in one building. The majority of materials used in this solution are lightweight. Only for structural or energy (e.g. thermal storage) proposes are used heavyweight materials.

  In order to show the thermal performance of a MBT solution it was selected an office building belonging to the Portuguese Electricity Company (EDP), located in Coimbra - Portugal.

  The building analysed (Figure 6) was rehabilitated using a MBT strategy only in the last floor whilst the first two floors kept the original conventional construction characteristics.

  The internal layout of the MBT floor is an open space (Figure 7).

Figure 6. Front and lateral view of the building

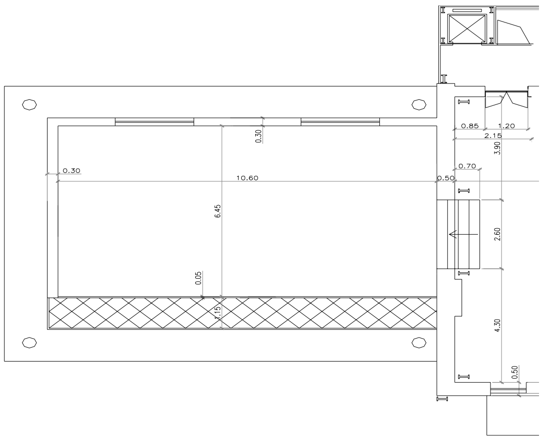

Figure 7. Schematic plan of the MBT building

The MBT building was compared with a virtual building, with the same geometry, but designed in a conventional way in what concerns the structure, walls, windows and roof.

The exterior walls in the MBT building have an overall conductance of 0.20 W/m^2.ºK, the floor 0.90 W/m^2.ºK, the roof 0.65 W/m^2.ºK and the windows 3.30 W/m^2.ºK.

The exterior walls in the conventional building were considered to have an overall conductance of 0.85 W/m^2.ºK, the floor 1.00 W/m^2.ºK, the roof 0,90 W/m^2.ºK and the windows 4,20 W/m^2.ºK.

The considered climatic data, for both seasons, was the one correspondent to sequences of typical winter and summer days corresponding to the building’s location

- Coimbra, denoted in the Portuguese thermal regulations as zone I1 and zone V2 for winter and for summer, respectively. The reference data for these zones considers an average heating degrees-day, in an 18ºC base, of 1460ºC/year, in winter, and an exterior design temperature of 33ºC for summer with temperature amplitude of 13ºC.

- <u>Thermal Evaluation</u>

  The energy consumption in both buildings (MBT and conventional one) was calculated according to the referred methods. Table 1 summarizes the annual heating and cooling needs, partial and total values, estimated for the analysed buildings.

Table 1 -Thermal performance of the MBT and Conventional buildings

		MBT Solution	**Conventional Solution**	**MBT / Conventional**
Heating Needs *[kWh/year]*				
- Opaque Exterior Envelope		1250	3185	↓ 61%
- Glazing		3788	2237	69%
- Air Renewal		2323	2323	0%
Useful Solar Gains [kWh/year]		3900	3514	11%
HN [kWh/year]		3461	4231	↓ 18%
Cooling Needs *[kWh/year]*				
- Opaque Exterior Envelope		327	484	↓ 32%
- Glazing	Without roller screen	3233	1491	117%
	With roller screen	1655		11 %
CN [kWh/year]	Without roller screen	3560	1975	80%
	With roller screen	1982		0%
HN + CN [kWh/year]	Without roller screen	7021	6206	13%
	With roller screen	5443		↓ 12%

- <u>Comments</u>

  This study shows that along a typical year, the overall energy needs in the MBT solution are 13% higher than the energy needs in the Conventional solution. However, in winter the MBT solution has a better performance since the heating needs are 18% lower than the ones of the Conventional solution. This best thermal behavior in the heating season is due to a better thermal insulation level of the building's opaque envelope, which makes possible a significant reduction on the heat losses through the building skin. Due to its solar strategy (South glass curtain), the MBT building has more useful solar gains (11% more) than the Conventional one. However, due to the same reasons, it also shows a greater glazing area, leading to a considerable increase in the heat losses (69% more).

  In summer the behavior is the opposite. The MBT building has cooling energy requirements 80% greater than the Conventional solution. In the final balance, the MBT solar strategy has a very negative impact. This worst behaviour is also due to the lack of thermal inertia in the MBT building. As previously referred, the MBT solution is a lightweight one leading to a light inertia building. The thermal inertia is responsible for the delay and amplitude decrease of the heat wave that enters into the building. The greater the thermal inertia the better indoor environment is achieved, preventing the risk of an overheating of the indoor air.

  About the solar exposure, the MBT building has a glass curtain wall in the South facade, two windows in the North facade and no openings in the East and West facades. The shading device placed on the roof is not enough to protect the south glass curtain in summer leading to large cooling needs.

Only through a better solar strategy exposition it is possible to reduce the cooling energy requirements in the MBT building. Table 1 also shows the results obtained in the case of having an interior roller screen in the MBT building activated during all the cooling season. In this case, the study shows that the cooling needs in the MBT building become equivalent to the ones in the Conventional building. Along a typical year, the overall energy needs in the MBT solution would be 12% lower than the energy needs in the Conventional solution.

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