THE OPTIMIZATION OF THE OVERALL PERFORMANCE OF BUILDINGS

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Summary

Building plan and shape are the result of a complex process. Functional, technical and aesthetic considerations all contribute to the building design. Wind, solar availability, shelter, exposure, air quality and noise conditions will affect the relationship between the building and its external environment and influence the shape and the design of the envelope. Materials selection, heating, cooling, daylighting, indoor air quality (IAQ), acoustic behaviour and energy strategies should be meshed at an early stage with the other requirements to ensure the buildings sustainability and overall comfort conditions.

To accomplish this goal it is necessary to predict the thermal, acoustic, lighting and IAQ behaviour of the buildings, on the design phase, in order to be able to do the right choices, regarding, for instance the geometry, fenestration strategies, construction solutions and materials, to improve the occupants overall comfort and, simultaneously, to reduce the energy costs and increasing the sustainability of the buildings.

So it is necessary to have an integrated approach to ensure the best overall behaviour taking into account all of the, sometimes incompatible, comfort and sustainability requirements.

The aim of this study is to select a range of optimized solutions (envelope construction solutions, materials, fenestration and ventilation strategies, etc.), in order to improve the overall performance of buildings (comfort and sustainability).

1. Introduction

As the building sector in the EU is responsible for 40% of the final energy demand (30% in Portugal) and of 1/3 of the greenhouse gases emissions, it is mandatory to control the energy consumption in the building sector, while maintaining or even improving the indoor comfort conditions and reducing the environmental impact.

Having this challenge in mind and considering that a healthy and comfortable indoor environment is a basic premise in all buildings, it is during the design phase that the sustainable building concepts should be applied, through the implementation of a combined strategic action that allows improving the comfort and the energy performance, while reducing the environmental impact, by a judicious selection of materials, technologies and construction methods to be used.

To achieve this goal it is necessary the use of environmental friendly products (to minimize the Volatile Organic Compounds - VOC - and other emissions), methods and techniques for buildings, re-use of components or use of recycled materials, minimize the use of materials or components that rely on scarce materials resources, select materials that balance durability and low embodied energy and design and plan the building for demolition and re-use and also to minimize the operation cost, namely the energy need for heating, cooling and domestic hot water.

To guarantee an adequate thermal, acoustic and daylight behaviour and the internal air quality (IAQ) of the buildings it is necessary to consider thermal storage (thermal inertia) using the building structure, selecting exterior walls systems and insulation according to the climatic zone, implement passive heating and cooling solar systems (using solar and photovoltaic panels).

It is also necessary to select the correct fenestration for each orientation, according to the latitude, lighting and natural ventilation, considering also the solar gains, the outdoor obstructions and choosing the shading devices to optimize the energy and comfort needs to ensure the acoustic and thermal exigencies, the indoor visual comfort related to the visual task to be performed.

It is necessary to optimize the building envelope, by improving insulation, glazing, optimizing natural ventilation and daylighting techniques through appropriate design in order to reduce the thermal losses of the building.

The solutions adopted in buildings, usually, only optimize no more than one of the necessary comfort requirements. In many cases, the best solutions to accomplish different comfort requirements are not compatible, especially in what concerns natural ventilation and lighting strategies and the acoustic and thermal performance. For instance, the type of window used can have a strong and opposite influence on the thermal and acoustic performance of the building, just not to mention its interference on the indoor air quality (IAQ).

The solutions adopted on the conventional buildings are only compatible with one or two of the necessary requirements, and don't fulfil the others (for example the windows' frame air tightness is good for the thermal and acoustic performance, but not to natural ventilation and doesn't interfere with the natural lightning). Therefore, it is necessary an integrated analysis to ensure the best overall behaviour (for instance, the definition of the area, shape, shading device, way of opening, type of glazing of a window, considering its orientation, the external environment, etc.).

Therefore, and as the buildings are complex systems, where all aspects are interconnected and influence each other, it is necessary to have an integrated approach to the building, that should enhance indoor health and comfort besides the energy savings and environmental sustainability, to ensure the best overall behaviour taking into account all of the, sometimes incompatible, comfort requirements.

The aim of this study is, then, to select a range of optimized solutions (envelope construction solutions, materials used, fenestration and ventilation strategies, etc.), in order to improve the overall performance of buildings accomplishing all the comfort requirements, because a well designed building has the potential to reduce energy costs and also to improve the occupants' comfort.

This study will consist on the optimization of the overall comfort conditions throughout the analysis and control of four major parameters related to the thermal insulation level, the acoustic insulation level, the illuminance levels (taking into account the indoor daylight requirements) and the number of air changes per hour (related to the indoor air quality), considering the factors that have influence on the buildings behaviour.

To achieve this goal a three bedroom dwelling, representative of the conventional Portuguese buildings, will be studied, estimating the heating and cooling needs necessary to maintain the indoor temperatures between 20 and 25ºC (comfort zone) according to the Portuguese thermal regulation (RCCTE, 2006), the acoustic behaviour of the envelope elements, estimating the weighted normalized airborne sound insulation index and the weighted normalized impact sound pressure level index, the indoor daylighting conditions, and the Indoor Air Quality (IAQ), for several construction solutions for its envelope and partition elements.

2. Methodology

To improve the overall performance of buildings it is necessary to select the right solutions (envelope construction solutions, materials, fenestration and ventilation strategies, etc.), considering the building characteristics, such as shape and orientation.

To evaluate the range of solutions, a three-bedroom dwelling, representing typical Portuguese buildings was selected in order to ascertain the potentialities of each one of the construction solutions and materials, in order to identify the ones that can improve the occupants overall comfort.

As, in general, in Portugal residential buildings are only acclimatized during occupied periods, the HVAC system was defined to maintain the indoor temperatures above 20ºC in winter and under 25ºC, in summer, according to the Portuguese legislation (RCCTE, 2006), only during this period.

The occupied period considered was between 7pm till 8 am and the non-occupied period between 8 am and 7 pm.

2.1 Simulation Tools

The Prediction of the building thermal behaviour will be done using computer modelling, with EnergyPlus, estimating the heating and cooling needs to maintain the indoor temperatures between 20 and 25ºC during the occupied period, for different construction solutions for the envelope and for the partition elements. The IAQ will be assessed by the number of air changes per hour (ach) ensured by the air inlets on the windows frame and by the mechanical ventilation of the WCs. In summer, during night periods the building is ventilated to use the cooler outside air to reduce the temperature inside the building. The number of hours where the occupants were uncomfortable in the zone was determined by EnergyPlus based on ASHRAE 55 - 2004 graph (Section 5.2.1.1) (ASHRAE 55, 2004).

The acoustic behaviour will be considered estimating the weighted normalized airborne sound insulation indexes and the weighted normalized impact sound pressure level index ($D_{n,w}$, $D_{2m,n,W}$ and $L'_{n,w}$), using the Acoubat Sound Program.

The lighting behaviour will be verified using the Desktop Radiance Tool, for the 21st of December and for the 21st of July, calculating the illuminance levels and the daylight factor which is the International Commission on Illumination (CIE from its French title) recommended method to determine the performance of a daylighting system, and is independent on the window design and location, outdoor obstructions, optical characteristics of inner surfaces and windows. It is useful for estimating the amount of glazing needed to illuminate a space.

2.2 Building Charateristics

The building under analysis, with 129.3 m^2, has three south oriented bedrooms. The kitchen and the dining and living room are north oriented (Figure 1).

The WCs are mechanically ventilated and the windows have adjustable air inlets in the frame to guarantee the ventilation of the dwelling.

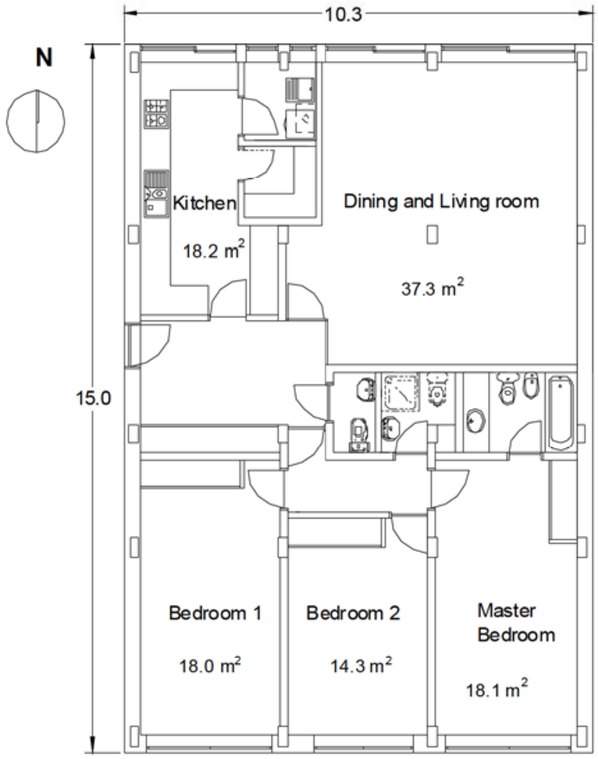

Figure 1 Schematic plan of the studied building

On an initial stage, the windows, with 1 m high, had a glazing area corresponding to 15% of the floor area (30% of the wall area), to maximize the use of the solar gains in winter and the daylight use (3.36 m^2 on the kitchen, 5.15 m^2 on the dining and living room, 2.75 m^2, 2.20 m^2 and 2.75 m^2 for the bedrooms). On a second stage, the glazing area was doubled to 30% of the floor area (window doors with 2 m high) to evaluate the influence of the window area on the energy needs, acoustic and daylight behaviour.

2.3 Construction Characteristics

The factors studied are the ones that need to be considered when designing the building envelope including amongst others: the area of windows, their orientation and type shading device used; the insulation levels used in the building; the air tightness of the building construction; the colour of the building and its surface properties; the potential for natural ventilation; and the amount of exposed internal thermal mass.

The construction solutions analyzed are shown in Figure 2 and listed on Table 1, for the different types of elements of the building envelope. The constructive solutions selected, single and double pane walls (hollow concrete blocks, brick, hollow brick and plasterboard), concrete, hollow core concrete and beam and pot slabs and materials (concrete, brick, plaster), cover a wide range of situations.

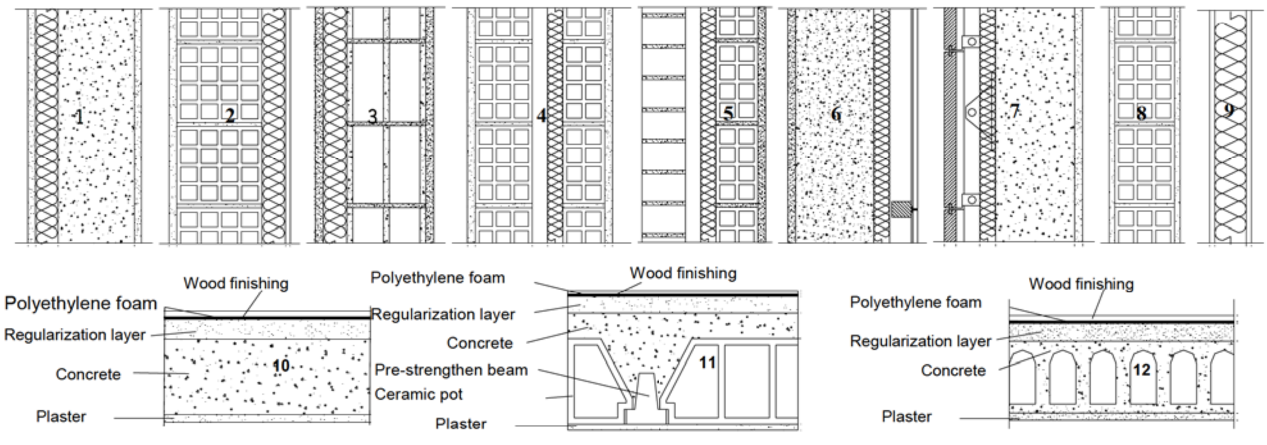

Figure 2 Vertical cross-section of some of the construction solutions of the buildings walls and floors (external and partition elements)

The study was done for two insulation materials (expanded extruded polystyrene, XPS, and mineral wool, MW), with several thickness (0, 2, 4, 6, 8 or 10cm). The insulation could be placed: in the exterior or in the interior of the single pane walls; or in air cavity or in the interior of the double pane walls (Figure 2).

The windows have an adjustable shading system (venetian blinds) on the outside to maximize the solar gains during winter and minimize the unwanted solar gains during summer and at the same time allowing the control of the daylight, thus, avoiding the use of artificial lighting.

Table 1 Construction solutions characteristics

Element	Construction Solutions (see Figure 2)	
Façade (with several insulation material thickness, finished with plaster on both sides)	Single pane concrete wall with 15cm (1) Single pane hollow brick wall with 22cm (2) Single pane hollow concrete wall with 20cm (3) Double pane wall, hollow brick with 15cm and hollow brick with 11cm (4) Double pane wall, brick with 11cm and hollow brick with 11cm (5) Double pane wall, concrete wall with 20cm and plasterboard wall with 1.3cm (6) Double pane wall, stone with 5cm and concrete wall with 15cm (7)	
Walls separating dwellings and common circulation zones	Double pane hollow brick wall (11cm + 11cm), with 4 cm of mineral wool in plates placed in the air cavity and finished with plaster on both sides	
Partition walls	Single pane hollow brick wall with 11cm, finished with plaster on both sides (8) Double pane plasterboard wall with 1.3cm and with 10cm mineral wool (9)	
Floors and ceilings	Concrete with 20cm, 4cm regularization layer, 0.5cm of polyethylene foam and 0.8cm of wood as top surface finishing and plaster as inferior surface finishing (10) Pre-stressed concrete "T" beams and 26cm hollow pots, 4cm regularization layer, 0.5cm of polyethylene foam and 0.8cm of wood as top surface finishing and plaster as inferior surface finishing (11) Hollow core concrete slab with 20 cm, 4cm regularization layer, 0.5cm of polyethylene foam, 0.8cm of wood as top surface finishing and plaster as inferior surface finishing (12)	
Windows	Metallic window frames with adjustable air inlets, venetian blinds on the outside and overhangs on south windows	Double pane clear glazing (8+10+6) mm Double pane Low-E glazing (6+10+4) mm

3 Results

3.1 Thermal behaviour

The typical Portuguese dwelling usually doesn't have HVAC systems and has double pane hollow brick walls (15cm + 11cm) with 4cm of expanded extruded polystyrene placed in the air cavity (solution 4 in Figure 2) and windows with metallic frame and double glazing. In this situation the inside temperatures are under 20ºC and above 25ºC, for long periods, as Figure 3 shows for the coolest and hottest day.

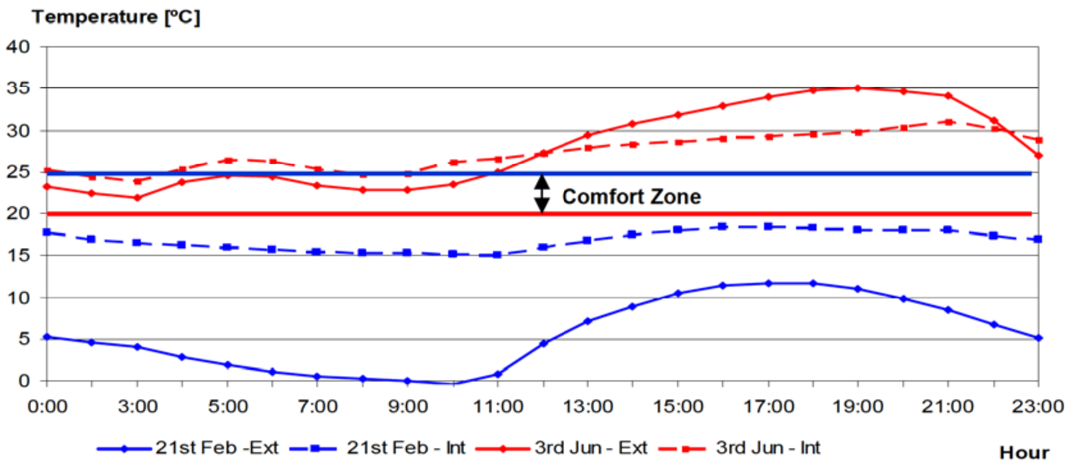

Figure 3 External and internal temperatures for the coolest and the hottest day – without HVAC.

So, it is necessary a mechanical system to maintain the indoor temperature above 20ºC in winter and under 25ºC in summer, during occupied period, which will mean a 3016.6kW/year consume (75% of which in winter).

On Table 2 are listed the heating and cooling needs and the comfortable period during occupied hours, for two different constructive solutions for single walls (a 15cm thick concrete wall, with plaster on the inside, and a 22cm thick hollow brick wall, finished with plaster on both sides), with several thickness of expanded extruded polystyrene on the outside and windows with 15% of the floor area (corresponding to 30% of the area of the wall).

Table 2 Thermal behaviour of the dwelling with single external walls and windows with 1m high

Constructive solution	Heating needs [kW/year]	Cooling needs [kW/year]	Heating + Cooling needs [kW/year]	Comfortable period [%]
Concrete wall with 15cm thickness, with several thickness of expanded extruded polystyrene placed on the outside				
Without insulation	3258.0	849.1	4107.2	36
2cm XPS	2546.4	748.4	3294.8	43
4cm XPS	2287.6	732.0	3019.6	48
6cm XPS	2161.1	726.8	2887.9	50
8cm XPS	2086.5	724.1	2810.6	52
10cm XPS	2037.2	722.5	2759.7	54
Brick wall with 22cm thickness, with several thickness of expanded extruded polystyrene placed on the outside				
Without insulation	3101.0	848.5	3949.5	38
2cm XPS	2481.7	745.2	3226.9	44
4cm XPS	2260.0	732.3	2992.3	48
6cm XPS	2146.6	728.2	2874.8	51
8cm XPS	2078.0	726.1	2804.1	52
10cm XPS	2032.0	724.5	2756.5	53

As Table 2 shows, a concrete wall has a worse thermal behaviour in winter than a single pane hollow brick wall with 22cm due to its higher conductivity, but during summer it has a better performance due to its higher thermal mass.

As can also be seen on Table 2, if the external walls don't have insulation, according to ASHRAE 55, only in 36% (concrete wall) or 38% (brick wall) of the occupied period the occupants were comfortable because not only of the low temperatures verified inside but also due to the radiation asymmetry between indoor walls surfaces and low surface temperatures. Increasing the insulation level, the number of comfortable hours is increased in 10%.

The same occurs when the windows are replaced for equivalent window doors (windows with 2m high which correspond to 30% of the pavement area and to 60% of the area of the wall)), duplicating the winter solar gains. In this case, both walls have a similar thermal behaviour, better during heating season than the one with windows with 1m high (15% of the pavement area, corresponding to 30% of the area of the wall), but worse during summer due to higher solar gains. For example for a single pane brick wall with 4cm of extruded expanded polystyrene, the heating needs are reduced in almost 30%, but the cooling needs are increased by 43%, resulting only in 3% reduction on the global needs.

The same kind of study was done considering the placement of the insulation material (on the outside or in the inside of single walls) and it was verified that the heating and cooling needs are similar and are more significant for higher mass and insulation levels and in the cooling period (5%), due to the effect on the thermal inertia.

The same type of analysis, but with windows doors with 2m high and Low-E glazing, was carried out. In this situation the solar gains were increased and the heat losses were reduced. In this case a concrete wall with 15cm and 6cm of expanded extruded polystyrene on the external face has a better thermal behaviour than a single pane hollow brick wall with 22cm and 10cm of expanded extruded polystyrene, and uses less space.

The reduction on the heating needs is of 24% and an increase of 37% on the cooling needs meaning a reduction of 4% in the global needs each year. The increase on the cooling needs due to the higher glazing area could be minimized with a better shading device or with the use of reflective glazing which will reduce also the solar gains during winter.

This study shows that it is necessary to pay attention to the glazing area and to the shading devices, because even with a good glazing and shading systems it is required to control the solar gains during summer.

The same kind of analysis was done for double pane walls. In this case it was verified that there are no significant differences (2%) in the thermal behaviour due to the type of insulation material (extruded expanded polystyrene or mineral wool). The differences on the energy needs, due to the different types of constructive solution (double pane walls with hollow concrete bocks, brick or hollow brick) are of about 3%, being smaller for the higher insulation thickness.

The increase on the insulation thickness can reduce the energy needs in more than 33%, for example when comparing a concrete wall without insulation and with 10cm of polystyrene expanded extruded, and a minimum of 4.6% when replacing 4cm by 6cm of the same insulation material.

Reducing the number of air changes per hour (from 1.0 to 0.6 ach, minimum value according to the Portuguese Thermal Regulation) will decrease the energy needs to almost 1/4, considering an optimized solution with 10cm of insulation and Low-E glazing. In this case there is no need to heat the space during winter (Figure 4).

In this situation the occupants will be comfortable in more than 80% of the time. In the other 20% of the time, the mean radiant temperature is under the desirable values.

Another possible approach is to reduce the north façade windows' area (kitchen and dining and living room), that have few heat gains, avoiding unnecessary heat losses.

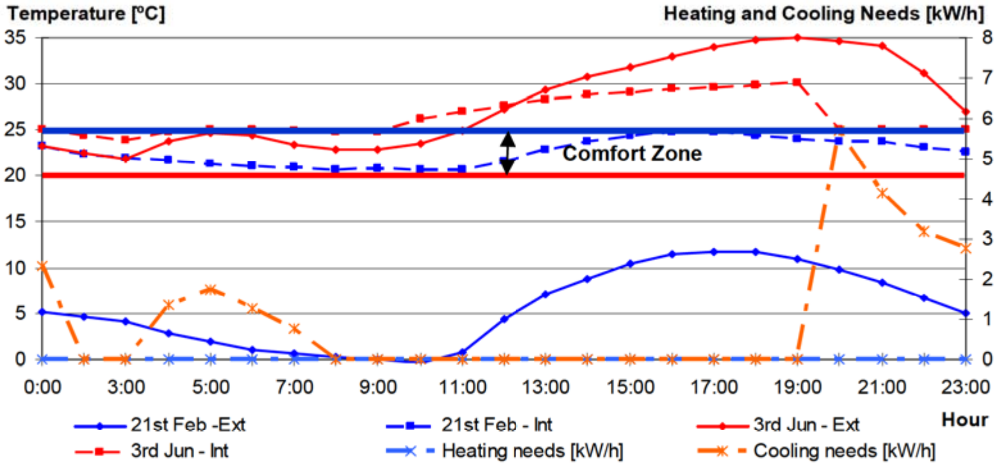

Figure 4 External and internal temperatures for the coolest and the hottest day – without HVAC

3.2 Acoustic behaviour

The acoustic requirements according to the Portuguese Building Acoustics Legislation (Decree-Law nº 129/2002) for residential buildings are the ones presented on Table 3.

Table 3 Acoustic requirements according to the Portuguese Building Acoustics Legislation (Decree-Law nº 129/2002)

Partitions	Weighted normalized airborne sound insulation index ($D_{n,W}$)	Impact sound insulation index ($L'_{n,w}$)
Between dwellings	≥ 50 dB	≤ 60 dB
Between dwellings and garages	≥ 50 dB	-
Separating dwellings from commercial areas	≥ 58 dB	≤ 50 dB
Between bed or living rooms and common circulation zones of the building	≥ 48 dB	≤ 60 dB
Between bedrooms or living rooms and vertical circulation paths (stairs), when the building has elevators	≥ 40 dB	-
Weighted normalized airborne sound insulation index of façades, measured at 2 m from them ($D_{2m,n,W}$)		
Sensitive zones (as defined on the Decree-Law nº 9/2007)	Exposed to $L_{den} \leq 55$ dB(A) and $L_{night} \leq 45$ dB(A)	≥ 28 dB
Mixed zones (as defined on the Decree-Law nº 9/2007)	Exposed to $L_{den} \leq 65$ dB(A) and $L_{night} \leq 55$ dB(A)	≥ 33 dB

On Table 4 are shown the estimated values for the weighted normalized airborne sound insulation index ($D_{n,w}$) and the weighted normalized impact sound pressure level index ($L'_{n,w}$) of the three studied floors.

The beam and pot slab studied don't fulfil the minimum requirements of the Portuguese Building Acoustics Legislation (Decree-Law nº 129/2002).

The concrete slab and the hollow core concrete slab fulfil the airborne, but not the impact insulation requirements.

Table 4 Acoustic behaviour ($D_{2m,n,W}$) of the dwelling floor

Element	$D_{n,W}$	$L'_{n,w}$
Concrete with 20cm, 4cm regularization layer, 0.5cm of polyethylene foam and 0.8cm of wood as top surface finishing and plaster as inferior surface finishing	52dB	67dB
Pre-stressed concrete "T" beams and 26cm hollow pots, 4cm regularization layer, 0.5cm of polyethylene foam and 0.8cm of wood as top surface finishing and plaster as inferior surface finishing	49dB	72dB
Hollow core concrete slab with 20 cm, 4cm regularization layer, 0.5cm of polyethylene foam, 0.8cm of wood as top surface finishing and plaster as inferior surface finishing	51dB	70dB

The acoustic behaviour of the floors, especially in what concerns the impact sound insulation, must be improved, using better resilient elements and floating pavements. A possible solution is the use of a resilient layer of expanded extruded polystyrene, which will improve the acoustic and also the thermal behaviour of the floor. This solution will fulfill the airborne and the impact insulation requirements ($D_{n,w}$ = 51dB and $L'_{n,w}$ = 57 dB). The wall separating dwellings and common circulation zones (double pane wall, hollow brick with 11cm and hollow brick with 11cm, with 4 cm of mineral wool in plates placed in the air cavity and finished with plaster on both sides) has a weighted normalized airborne sound insulation index, $D_{n,w}$, of 50 dB, fulfilling the exigencies of the Portuguese acoustic regulation. In the partition wall (single pane hollow brick wall with 11cm) the $D_{n,w}$ is of 38 dB.

On Table 5 are shown the estimated values for the weighted normalized airborne sound insulation index of the façade ($D_{2m,\,n,\,W}$). For the situation under analysis, almost all the cases fulfil the Portuguese acoustic regulation. The exceptions are the kitchen and the dining and living room with 2m high windows. As Table 5 shows, for external walls with 4cm of expanded extruded polystyrene and for the two types of windows (1 m and 2 m high, corresponding to 15% or 30% of the area of the wall, respectively)), there are no significant differences considering the different constructive solutions, as they are all heavy. However, comparing the performance of the situation with 1m and with 2m high windows, there are differences of 2 dB. So, to improve the quality of the façade walls it is essential to balance the window area and the acoustic quality of the glazing.

The reduction on the north windows area, as previously suggested, will also have a favourable effect on the acoustic behaviour.

Table 5 Acoustic behaviour ($D_{2m,n,W}$) of the dwelling external walls

Constructive solution	Single pane walls with 4cm of polystyrene expanded extruded on the outside		Double pane walls with 4cm of polystyrene expanded extruded on the air cavity	
	Concrete 15cm	Hollow brick 22cm	Hollow brick and hollow brick (15+11)cm	Massive and hollow brick (11+11)cm
Double glazed windows (6+10+8) mm with 1m high (15% of the pavement area and 30% of the area of the wall)				
Kitchen	34	34	34	34
Dining and living room	33	33	33	33
Bedroom 1	34	34	34	34
Bedroom 2	35	35	35	35
Double glazed windows (6+10+8) mm with 2m high (30% of the pavement area and 60% of the area of the wall)				
Kitchen	32	32	32	32
Dining and living room	31	31	31	31
Bedroom 1	33	33	33	33
Bedroom 2	33	33	33	33

Traditionally Portuguese buildings are heavy ones, and the study performed shows that in general the façade fulfil the requirements, for the case where the glazing has 1m high (area is of about 15% of the pavement area, corresponding to 30% of the area of the wall), if the windows area is doubled the requirements are not verified. So, in this case it is necessary to increase the quality of the windows.

3.3 Daylighting behaviour

The illuminance levels and the daylight factor for an overcast sky, recommended by CIE, are shown on Table 6 (CIE, 1975). Figure 5 shows the illuminance levels and the daylight factor for the 21st of December and for the 21st of July, for the bedroom 2, for windows with 1 m high (15% of the pavement area, corresponding to 30% of the area of the wall).

Table 6 Illuminance and Daylight factor for an overcast sky (CIE, 1975)

Illuminance Levels (Lux)		Daylight Factor (%)	
Dining room	100	Bedroom	0.5% at 3/4 of room depth
Living room, kitchen	200	kitchen	2% at 3/4 of room depth
Study	300 - 500	Living room	1% at 3/4 of room depth

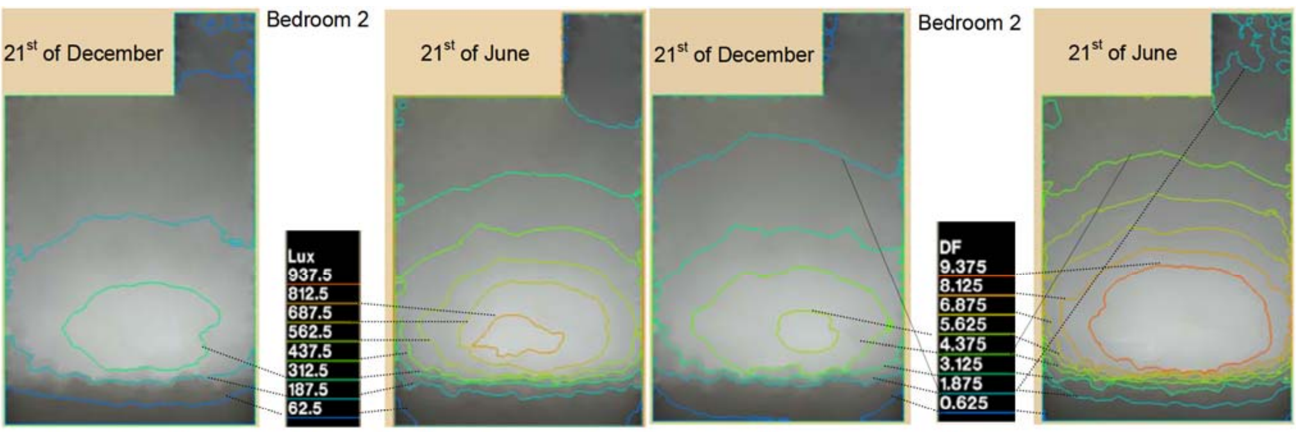

Figure 5 Illuminance Level and Daylight Factor for the bedroom 2, for an overcast sky

The recommended illuminance levels for the studied zones in winter are respected only on the area near the window, and in almost space during summer, but, for the Portuguese luminous climate, the recommended external minimum illuminance considered for an overcast sky is exceeded in more than 90% of the time during the year (Silva, 2002). According to the CIE recommendations, a daylight factor of 2% - 5% is usually the optimum rage of daylighting for overall energy use, and considering the recommended daylight factors for bedrooms these values are fulfilled during winter, but are largely overcome in summer or even in winter when the windows have 2 m high (30% of the pavement area, corresponding to 60% of the area of the wall) (CIE, 1975). The reduction on the north windows area will also have a favourable effect on the daylight behaviour, minimizing the glare, as, even in winter, in the zones nearest to the windows, the daylight factor and the illuminance levels will be high.

3.4 Global behaviour

Analyzing the results of the study it was possible to verify that, even with conventional solutions used in Portugal, it is possible to achieve a good global behaviour, considering the buildings' thermal, acoustic and daylight behaviour, but it is necessary to increase the insulation level of the external walls, and the acoustic quality of the glazing. It is also necessary to improve the acoustic behaviour of the pavements, increasing the quality of the resilient layer and using floating pavements.

5 Conclusions

From the analysis performed it was possible to conclude that there are a great number of constructive solutions, that when adequately used will fulfil the comfort exigencies.

In Portugal it is necessary to improve the thermal insulation levels of the façades and the acoustic quality of the glazing parts of the façade. It is also necessary to use windows with improved frames, with low permeability, to guarantee that the number of air changes per hour is of 0.6.

The selection of the shading devices must also be done carefully to reduce the heat losses during the heating season and the heat gains during the cooling season, and at the same time allowing the penetration of natural light and not reducing the acoustic behaviour of the façade.

The improvement of the night cooling of the buildings with high thermal inertia, during summer, and with the control of the radiation that penetrates into the building will also improve the thermal behaviour of the building.

The shading devices must be movable allowing the control of the radiation but, at the same time admit the entrance of the daylight, control the glare and adjust for variations on daylight availability.

The acoustic behaviour of the conventional floors and of the windows must be improved.

It is necessary to select the correct fenestration for each orientation, according to the latitude, lighting and natural ventilation, considering the solar gains, the outdoor obstructions and choosing the shading devices to optimize the energy and comfort needs to ensure the acoustic and thermal exigencies, the internal air quality and the indoor visual comfort.

But through the integrated approach to the building performance it was possible to conclude that the overall comfort exigencies are not restrictive, because there are a large number of constructive solutions that will assure all the requirements being only necessary to integrate the exigencies of the different requirements.

The windows area and the quality of the frame, the glazing and the shading device are the most important factors to take into account to fulfil the overall comfort requirements. The solution adopted for the fenestration must be selected carefully and may be different for each orientation.

The optimization of the building envelope, by improving insulation, glazing, and optimizing natural ventilation and daylighting techniques through appropriate design in order to improve the overall comfort does not limit the creative process of the designer.

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