THE ENERGETIC PERFORMANCE OF OLD BUILDINGS: HOW TO IMPROVE IT?

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Abstract

Along the years, in Portugal, the built environment was left behind and the straights were devoted for new buildings, creating new urban areas sometimes unattached from the existing city. The construction before the 80's is compromised by its thermal quality if we consider that the thermal codes and the worry about thermal buildings behavior only came up around 90's. In this work, the buildings from old city centers and its characteristics were studied as well as some intervention actions accurate for this construction and its results in terms of thermal performance. For this study a simulation tool was used, namely the Design Builder, and the results of these simulations were presented in order to understand the improvement in its thermal behavior when compared with its original conditions.

It is possible to improve considerably the interior comfort and buildings thermal behavior with respect by architectonic characteristics and keeping constructive solutions and material with interventions actions that are compatible with existing structures.

Keywords: Buildings Thermal Behavior, Old Buildings, Thermal Simulations

Introduction

The built environment is only one of the axes of development that can be found in the complexity inherent in sustainable development. The construction and use of buildings is an important factor in the global arena. The buildings and structures use raw materials, some of which are non-renewable; energy is use to extract these materials and to manufacture instruments / machines / technology and, once on the structure, they affect the heating and cooling of interior space. The way people use space can also affect energy requirements (Graham, 2003; Kibert, 1994; 2002).

The environment determines the human need for a certain type of housing, and the built environment is largely determined by the communities that inhabit them and the buildings reflect the needs of individuals and groups, culture and location of structures (Newman & Jennings, 2008).

The quality of housing is a need that must be met without compromising the existing ecosystems, demanding that firms adopt an ethic of valuing the environment. The quality is qualified from the definition of demand, possible to notice in the constructive project through the fulfilling of social, economic and environmental aspects.

Until the 70's, Portugal has promoted some policies that didn't reverted to the preservation of urban areas, it was a time marked by the search for the "original design" involving the destruction of parts of the urban fabric, without respecting the process of transformation of the city, a process with high state and centralized costs.

The null increase of rents in rented property in Lisbon and Oporto, beginning in the 40's, made it impossible to preserve buildings by the owners due to low incomes. In the 70's starts the transition between the isolated safeguarding of buildings to a perspective of urban intervention, considering concerns at the planning level. During this period some legal instruments to safeguard are provided and some funding programs are created. In the 80's are designed Protection and Valuation Plans, specific to historical centers and regulations are made in the field of buildings intervention in these areas.

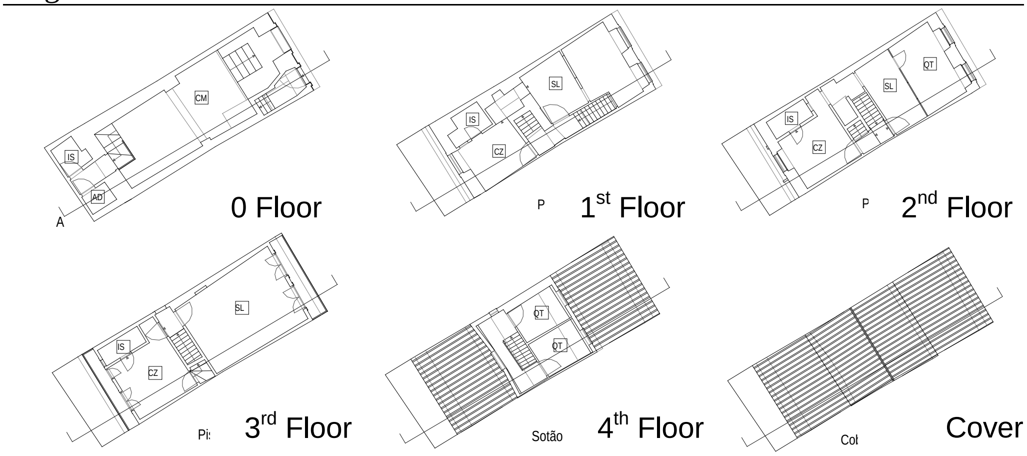
In the 90's a Thermal Code came up with new developments about the interior comfort and the envelope exigencies. Along the last years it has evoluting with the implementation of an Energetic Certification System as a result from a European Directive transposition. So, nowadays, the thermal rehabilitation have been facing as a strong aspect to conduct interventions in old buildings, guiding interventions and defining actions.

Case Study

The old town of Coimbra, better known as the Lower Town, was studied in detail using the database at the University of Coimbra that holds information about the general characteristics of this area, including aspects related to engineering and architecture, and considers: architectural and photographic survey, constructive characterization of the building, pathologies and other relevant information to a systematic knowledge of this urban space.

With all these data was possible to study the buildings characteristics and analysing its thermal comfort before and after interventions towards an energetic rehabilitation. The energetic rehabilitation aims to improve the building energetic performance creating more suitable comfort conditions, besides improving the economy and the rational consume of energy. It's possible to classify the interventions in this area according to four types of actions: increasing of thermal resistance (reducing U value); controlling air infiltrations; using passive solar technologies and improving the efficiency of energetic equipment and systems. These actions can be implemented according to several solutions which are following presented as well as contributes to the elaboration of an analysis about its application in old buildings. (Aguiar et. al., 2001)

Using two landmark buildings, as an example of the type existing in old urban areas, it was possible to apply the model and define the performance graph of each one. One of these buildings is illustrated in Figures 1 and 2.



Abbreviations: CM – commerce; AD – storeroom/storage; IS – toilet; CZ – kitchen; SL – livingroom; QT – bedroom.

Figure 1 Plants of one of the buildings

According to Figure 1 it's possible to understand the type of organization of spaces, as well as the volume of construction. The buildings are mostly side by side, which means that only two facades are free and possess glazing (usually in the lower facade). In some cases there are interior compartments without lighting or natural ventilation. This housing is an example of the type of buildings located in old areas: although there are features and materials specific to certain regions of Portugal, the shape and internal organization are similar.

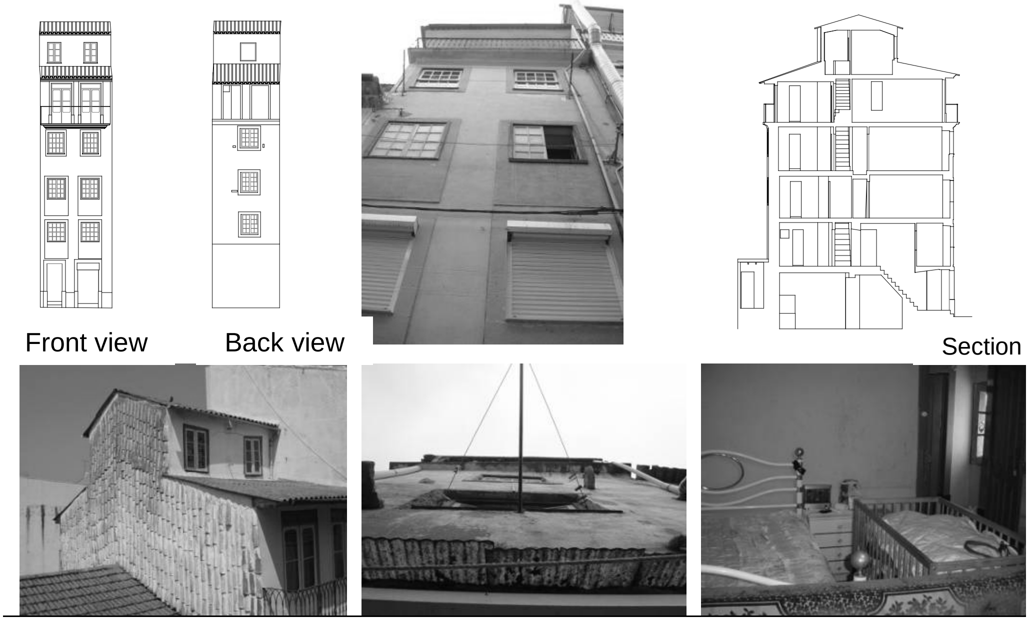


Figure 2. Buildings' images

Analysing the results from simulation

The simulations were done in the Design Builder software and taking into account different situations:

- Situation A – Buildings isolated considering its original characteristics (exterior walls with limestone; interior walls with "tabique" – light wood structure with mortar; walls among between buildings with "frontais" – wood structure with small pieces of stone and brick, finishing with mortar; floor with wood structure; roof with wood structure and ceramic tiles).
- Situation B – Building with the surroundings, but considering the other buildings as surfaces in the Design Builder.
- Situation C - Building with the surroundings, but considering the other buildings with the same constructive characteristics as the original one.

In a second moment, considering the situation A, were done the following improvements in the exterior facade:

- Change A-PI – Applying thermal insulation in the exterior walls, but in its interior surface.
- Change A-PI CD – Applying a double frame, with double glass and keeping the original wood frame with simple glass, besides the use of thermal insulation in the exterior wall as the previous change.

In Figure 1 we can observe the model designed and used for thermal simulation.

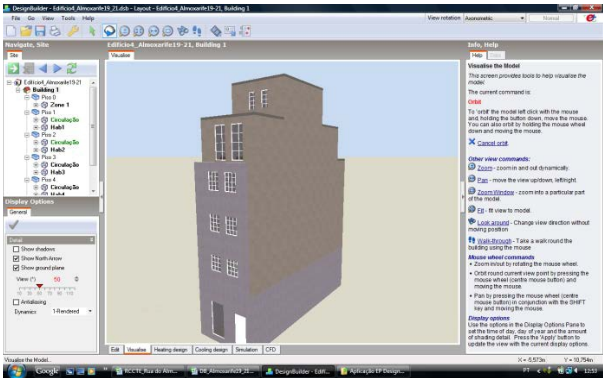


Figure 1. DesignBuilder Interface with the model used

The results from these simulations can be observed in the Table 1 (values in Kwh):

Table 1. Results from Design Builder simulations

Case Study - 1st Floor									
Situation	Description	Glazed Surfaces	Walls	Roof	Floor	Air leakage	Needs		Solar gains
							Heating	Lighting	
A	Isolated	-461,29	-352,04	0,05	-288,27	-586,34	263,93	204,58	1000,28
B	Surrondings with surfaces	-451,97	-338,85	0,05	-264,86	-580,11	267,41	210,2	938,739
C	Surrondings with buildings	-459,67	-511,96	-0,05	-226,96	-965,5	425,03	397,51	715,54
Changes									
A-PI	Insulated walls	-452,49	-121,26	0,08	-274,22	-572,71	149,77	206,03	843,06
A-PI CD	Insulated walls Double frame	-273,86	-127,08	0,24	-299,7	-584,49	115,67	208,07	736,85

Case Study - 4th anf 5th Floor									
Situation	Description	Glazed Surfaces	Walls	Roof	Floor	Air leakage	Needs		Solar gains
							Heating	Lighting	
A	Isolated	-1595,99	-3933,37	-198,56	0,28	-827,76	2575,15	313,28	3017,13
B	Surrondings with surfaces	-1595,99	-3933,37	-198,56	0,28	-827,76	2575,15	313,28	3017,13
C	Surrondings with buildings	-1506,18	-3915,75	-198,45	0,11	-814,60	2660,83	328,16	2859,21
Changes									
A-PI	Insulated walls	-2068,54	-1713,02	-208,39	-0,11	-1004,38	1115,34	311,02	3017,13
A-PI CD	Insulated walls Double frame	-1013,26	-2255,76	-246,90	-0,16	-1005,62	1101,53	312,94	2564,57

The Table 2 present the variations in the results considering the improvement provided by the changes (A-PI and A-PI CD) and having in mind the overall balance through the total amount of losses and gains.

Table 2. Variation in the results

Housing building	**Changes**	Thermal reinforcement	Overall Balance	Balance	Variation
1st floor	**A-PI**	Masonry	-687,61	577,54	-16,0%
	A-PI CD	Masonry + Frame		-548,04	-20,2%
4th and 5th floor	**A-PI**	Masonry	-3538,27	-1977,31	-44,1%
	A-PI CD	Masonry + Frame		-1957,13	-44,7%

With the change A-PI we can observe an improvement of less 16% of losses in 1^{st} floor and less 44% in 4^{th} and 5^{th} floors, but when are considered the two proposed changes these values increased to 20% in the 1st floor and it remains around the same value in the last two floors (from 44,1% to 44,7%).

The results are dynamic and intervention on an element causes the variation of another. For example, in the case of differences between the application of thermal insulation in the masonary, it causes an increase of losses in the glazing surface.

Reinforcing thermal resistance on glazed surfaces after improving the opaque surface will not reverse in significant benefits due to the above effect. It is also important to mention the small size and lack of glazing areas which also contributes to the results expressed by those factors are not significant in the overall housing performance.

The Table 3 compares the results for each solution and according to three mains aspects: the losses through the walls, the heating needs and the solar gains through the glazed surfaces. The changes will contribute in different ways according to each element analysed. The changes on the walls will contribute with very similar results for each situation defined (A, B and C), but the heating needs will be higher in solution A than in solution C, maybe it can be explained by the thermal inertia in the area and the heat island effect.

Table 3. Results comparing the changes in each different solution

Simulations		**Solution A**	**Solution B**	**Solution C**
A-PI	Walls	34,4%	35,8%	23,7%
	Heating Needs	56,7%	56,0%	35,2%
	Solar Gains	84,3%	89,8%	117,8%
A-PI CD	Walls	36,1%	37,5%	24,8%
	Heating Needs	43,8%	43,3%	27,2%
	Solar Gains	73,7%	78,5%	103,0%

The solar gains will present the higher variation in the results, with higher values in Solution C, when the simulation was done considering the buildings in the surroundings. It might be explained by the solar incidence and reflexion that will improve the amount of solar radiation that reach the building and its glazing surfaces.

Conclusions

Given the need to reduce energy consumption as a way to decrease the impact of human activity on the environment, the analysis of this part of the built environment is fundamental when considering the needs arising from the quality of these buildings. The built environment has to be improved in order to contribute for a better thermal performance of the urban areas, decreasing the production of green gas emissions as results of processes to produce energy.

The present work shows that traditional buildings, which show adverse construction characteristics in face of the techniques and materials available today in the construction industry, have a poor indoor environment quality. Is important to mention that this work did not consider the significant degradation of the buildings which affect negatively the initial results (considering the existing building).

The simulations shown that small interventions can have significant results at the level of the indoor environmental conditions and of the energy consumption in these buildings to achieve minimum levels of comfort (being used the standards parameters defined by the software). The thermal enhancement of the vertical opaque surrounding, in particular by thermal walls and glazing strengthening, can contribute to about 16 to 44% of reduction in overall losses of the building.

The heat island effect is an aspect that need to be deeply approached in this urban area. The buildings characteristics, with stone walls and strong thermal inertia, and the urban mesh, with narrow streets almost without public or private green spaces, give us the idea that a microclimate can be created through the solar radiation absorption by the surroundings, so a specific study in this area should be developed in the nearest future.

The improvement of these buildings is a key strategy for recovering degraded urban areas to control the spreading out of the city. The paradigm of sustainable development has imposed a fundamental condition for human existence: the control over the occupation and the impact on the environment. This occupation has been characterized by the destruction and excessive consumption of resources. The contribution of these urban areas could be significant if the society assume its recovery as an alternative to new construction.

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