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Computing the Thermal Energy Performance of Building by Virtue of Building Dimensional Typology

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Abstract

The constructive particularities of Portuguese old buildings, with specific and ancient constructive solutions and buildings' aesthetics, determine the type of interventions and turn some of the most efficient interventions impossible to apply. Since the external appearance of buildings in old city centers must be preserved, nor is the use of external isolation not an alternative, neither the use of materials with low hygro-scopicity, due to the nature of the material used in exterior walls, usually stone. Presented research was expanded to figure out the reaction of different intervention solutions which are used in old buildings' envelope to accomplish their energy performance. The old city center of Coimbra has a building typology very characteristic and similar to other Old Portuguese city centers, so the idea was to create a representative building of their dimensional characteristics. The modeled building unit was designed after studying around thirty buildings. With all the collected data, it was possible to design a building which we consider that as representative of Coimbra City Centre buildings. This modelled building was used to simulate, with Design Builder software, in real condition and with different solutions for interventions in facades, to predicting the thermal performance achieved for each one. Their final performance was analyzed and compared. The achieved results will be used to define the most suitable interventions in old buildings to improve its energy performance beside of good indoor air quality.

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1. Introduction

Energy use in buildings is a significant factor in world's overall energy consumption and a major contributor to greenhouse gases emissions. According to the National Information System for Energy, residential buildings consume over half of the electricity [1]. The current main source of energy in Portuguese households is electricity, representing about 42, 6% of the total energy consumption [2]. Buildings also contribute to 45% of the country's greenhouse gas (GHG) emissions, which are linked directly to global climate change [3]. About 80% of the energy consumed in the commercial and residential buildings is used for space heating and cooling. Despite numerous European studies carried out during the past decades dealing with the assessment of various Energy Conservation Measures (ECMs) on the energy performance of buildings, it is a fact that little is actually known regarding the European building stock, its characteristics and current trends. Additionally, the assessment of the building stock has gained a lot of interest as a result of the concerted European efforts to comply with the mandates of the Energy Performance Building Directive – EPBD (2002/91/EC). Enhanced thermal protection is therefore a pre-requisite to construct or rehabilitate buildings to reach a reasonable energy consumption, satisfactory thermal comfort conditions and low operational costs. The energy efficiency requirements of building envelope have always been an essential part of nearly all regulations since its improvement represents a major energy saving potential [4] So, energy saving can be obtained by insulation since significant part of heat losses or heat gains occurs through opaque envelope [5].

1.1. Sustainable Rehabilitation and building typology

The sustainable construction principles are applied when existing materials and structures can be reutilized, instead of replaced by new ones. The sustainability and energy issues are included in the agenda of many European governments [6]. Old buildings need conservation, indoor comfort and better energy performance to reach the functionalities required by the modern society's way of living. Studies made so far consider that historic architecture can often be adapted to meet modern requirements without losing heritage value and that is one of the important strategies to reduce carbon emissions [7]. Building typologies can be used for an in-depth understanding of the energy performance of a building stock [8]. Typological data and criteria are currently used on national and regional level for the elaboration of information material and for issuing energy advice. Representative residential building typologies are also serving as an instrument for modelling the energy performance of building portfolios in order to support regional or national energy saving policies. The term "building typology" describes a classification of buildings according to some specific characteristics, which in this case are related to the building energy performance [8]. The energy consumption in buildings depends on a number of factors including the envelope constitution, age distribution of the existing building stock, outdoor weather conditions, dimension of buildings, and type, age and efficiency of system installations. The year of building construction provides useful insight information with regard to the type of envelope construction, in accordance to the national building standards in force at that time. European statistics reveals that 14% of European building-stock dates before 1919 and 12% between 1919 and 1945 [9]. According to the most recent available data from INE, Portugal has 5.878.756 accommodations in a total of 3.518.152 buildings [10]. Old buildings, built before the year 1945, represent 14, 4% of the Portuguese building stock [2].

Table 1. Relation between buildings age and repair needs [10].

Construction Time (age)	Before 1919		Between1919-1945	
Between1919-1945	N.	%	N.	%
Without repair needs	77.326	2.18	125.924	3.55
With repair needs	106.616	3.01	162.017	4.57
Very degraded	22.381	0.63	17.755	0.5
Total	206.343	5.82	305.696	8.62

According to data from the 2001 Census, about 62% of the residential building stock that were built in Portugal in the 1946- 1960, 1960s, 1970s and 1980s needed some kind of rehabilitation on their structure (6.0%), roofs (7.7%) or walls/windows (8.6%). The majority of the energy is used in buildings built in these periods (between 1946 -1980s). These buildings are the ones with higher energy needs and simultaneously with greater needs of retrofitting. It is estimated that 19% of Portuguese existing buildings stocks built before 1945 does not have concrete structure [11]. The first Portuguese building thermal insulation regulation (RCCTE) took effect in 1991 setting the minimum requirements for thermal transmission of the building envelope for different climate zones. Buildings constructed before 1991 (pre-1990) were built without any specific concerns related to the thermal insulation of the envelope or to their thermal behavior [10]. Since, the housing stock of historic centers in Portugal is generally composed by buildings with important characteristics from a historical and architectural point of view (Article 136 Legislative Decree No. 42/04), based on the latest Portuguese Law (32/2012) [12], the activity of preserving historic centers towards the maintenance of buildings physical integrity must be done in order to conservation of the heritage and historical fabric to and from the old town centers [13].

2. Research Methodology and Case Study

Generally the classification of the residential building stock in Portugal is divided to four construction periods – age bands (pre-1945, 1945–1980, 1980–2000 and after 2000), two sizes (single family, multifamily) and three climatic zones for each season (summer and winter). In order to discover the geometrical typology of buildings, the analysis of 30 old residential buildings in Coimbra city center was developed to know the properties of facades and envelope orientation to find datasets of the typology include general features (i.e. number of stores, living area) and geometrical data (i.e. building volume, envelope areas). The results of these analyses were used to find the average area of each element and get a building-type that it is representative of the buildings standing on the historic center of Coimbra. After finding the building typology, a 3-dimensional model of case study has been simulated in Design Builder software. The simulated residential building has an area of 217m2 and 4 floors in which the ground floor is considered a commercial space.

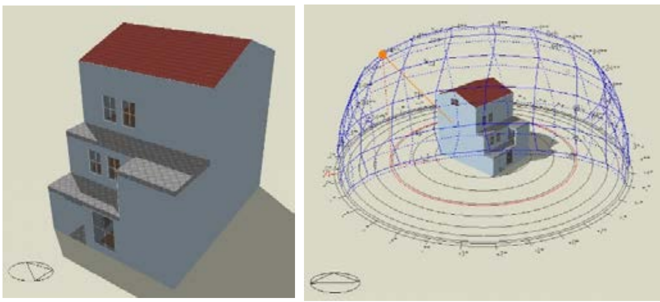

Fig. 1. Simulated model of existing building based on the numerical typology results.

3. Result Analysis and Discussion

Two scenarios were defined for analyzing the energy performance of the case study: a “standard” scenario and an “ambitious” scenario. The standard scenario includes the real condition of building, in order to obtain the numerical results for energy building behavior considering the use of existing and real materials and construction solutions.

3.1. Energy performance analysis of the building based on the standard scenario.

Figure 2 illustrates the calculated heat gains and energy consumption of the building in annual period. Overall it shows that the difference among air temperature, operative temperature and outside temperature are high, and this difference in winter time is much clearer than summer time. (Temperatures present a variation from 4 to 10 degrees Celsius).

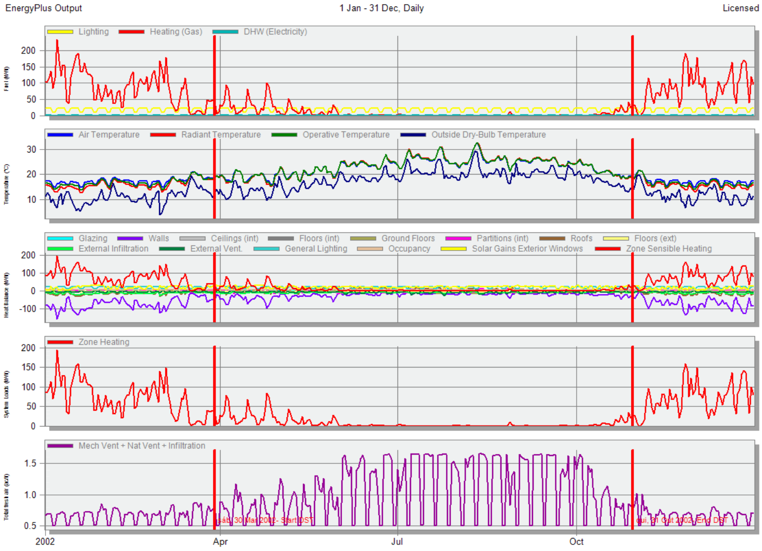

Fig. 2. General analysis of energy performance of building in annual period.

Based on the first chart of the presented result, the building needs too much energy for heating and it is more than the energy needs for lighting or DWH, for instance in winter period in some mounts the building needs to consume about 200 kwh/m2 energy for heating although based on the Portuguese energy certificate (REH) the amount of energy consumption in existing buildings must be between 46-125 kwh/m2 depending on the climate zone. This means that the maximum energy consumption in coldest climate zone (north of Portugal) cannot be more than 125 kwh/m2. But as it is showed in this result, the amount of energy consumption just for heating a building in Coimbra (center of Portugal) is upper than the allowed maximum value.

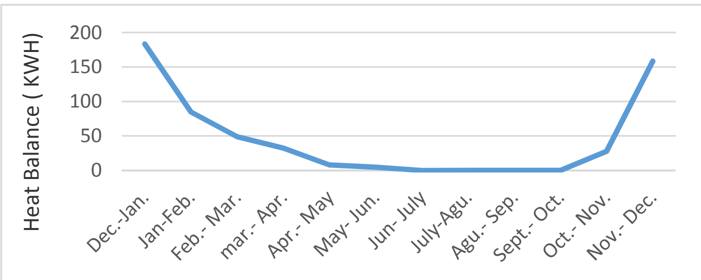

Fig. 3. General analysis of zone sensible heating needs of building in annual period.

On the other hand, based on the third and fourth charts of figure 2 and also figure 3, the heating sensibility of building is high and, as shown, this condition continues until May, although based on the climate of Coimbra, the outside temperature in May or June is high enough to not be necessary to consume energy for heating, but based on the obtained results, inside conditions of building are not in a sufficiently fine level even in mounts with good outside temperature. Beside of the high heating sensibility of the building, the third chart of Fig. 3 also shows that, the heat balance of the wall is really weak and it means that the amount of heat losses through the walls are higher than the ones registered in other elements. External infiltration and ground floor are placed in next ranking. The problem of heat balance in wall happened exactly in the same period in which the heating sensibility of building is high. Thus, all these reasons confirm that the energy performance of buildings, as expected, is weak and the resident have to consume too much energy for making building condition appropriate for living (comfortable condition). According to the presented result, it can be observed that the thermal behavior of buildings needs to be improved, namely in winter when the weaker performance was observed. The building also has too much heat losses through the walls in winter period which meaning that the energy performance of building has not been placed in a sufficient level. Because as presented in this result, the building skin has effect in the percent of heat gain and heat lose through the external surfaces. According to the previous discussion, the majority of the buildings before 1991 are considered non-insulated, while most of the buildings of the period 1980–2000 are partly or insufficiently insulated. The most common retrofit intervention in old buildings is the addition of insulation and the replacement of single glazing by double ones which it is selected as ambitious scenario. The goal of this research is to understand the thermal behavior of the building based on two scenarios, in the real situation (standard scenario) and improving its energy performance with better constructive solutions in energy performance terms (ambitious scenario), so the model has been developed by adding four different thermal protection solutions. For this purpose, the first change was adding a thermal insulation layer on existing envelope. To add this thermal insulation layer, four different thermal insulation materials were performed: Expanded Polystyrene (EPS) as one of the most popular insulation material in Portuguese market, Agglomerate of Expanded Cork (ICB) as an organic material characteristic from Portugal, Polyurethane (PUR) and Phase Change Material (PCM) as two new materials in the thermal insulation market, have been selected and second change was replacing the glazing of opening with double one. Based on the presented reasons of historical values of area, ICOMOS and Portuguese Law, it is a role to keep the exterior appearance of buildings. For instance, all selected intervention actions were done in the inner surface of envelope. In the second step of this section, after considering the described solutions before, the simulations of building thermal performance were carried out for each one of them. The results are presented in figure 4.

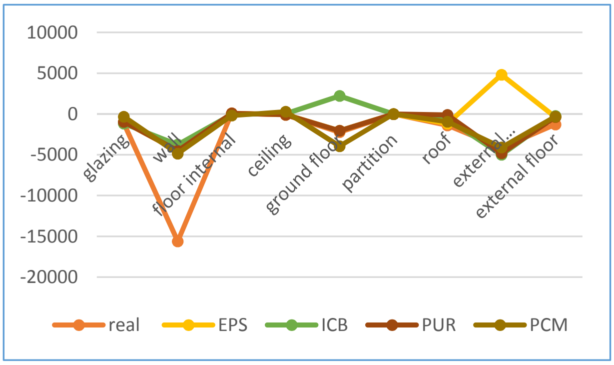

Fig. 4. Comparative analysis of heat loss and heat gain on residential building with thermal insulation and without.

Figure 4 illustrates that adding thermal insulation material to the building walls as a solution to improve its thermal performance will represent a great improvement in its efficiency through the enhancement of its thermal behavior. As it was shown in the Figure 6, with adding thermal protection, the amount of heating loss in the wall envelope will be extremely decreased as well as the heat losses through external floor after adding thermal insulation layer in the structure system of building. Also the external infiltration condition is also extremely improved.

4. Conclusion

In order to reduce the energy consumption in buildings, however, one needs to understand patterns of energy usage and heat transfer as well as characteristics of building structures, operations and occupant behaviors that influence energy consumption. The building typology concept as proposed by a European collaborative effort has proved to provide a flexible tool for estimating the impact of energy saving scenarios on the energy performance of the residential building stock. On a national level, building typology can be used as a model for imaging the energy consumption of the residential building stock in a country. In the long run, the national building typologies can be used as data sources for forecasting and evaluating the energy savings and CO_2 emission reduction for each European member state. This understanding can be aided through the development of scientific models which are based on physics, mathematics and statistics. The present work has performed a case study to demonstrate the use of building typology to model the national energy balance in Coimbra. Even ambitious scenario that prioritizes proper thermal insulation of the buildings' thermal envelope (according to the new national thermal regulation), exploiting energy efficient heat production units and minimizing heat distribution losses, can result in significant energy savings. For example, applying the provisions of the standard scenario to 15% of the residential buildings built prior to 1990 (without thermal insulation) and 30% of the buildings built between 1990 and 2000, can help reach the national indicative target of 9% energy savings in the residential building sector by 2016. Based on this research, the scientific model of geometrical typology has been drawn based on characterization of the building's physics. This scientific model has helped to understand that the energy performance in existing buildings is not at a good level which needs to be changed. This change can be in different levels like structural, operational, behavioral, etc. This research has been developed based on the structural change which it means, retrofit actions. In this research, with adding a thermal insulation layer and changing the glazing of opening to double glazing have been tried to improve the thermal behavior of buildings envelope. The simulated model of possible solutions to improve building condition can be used to understand the energy use, comfort level and also Green House Gas (GHG) emissions. It can also provide a decision support to make buildings more energy efficient.

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References

[1] EC, "Acção da UE contra as alterações climáticas". Available at: http://ec.europa.eu/climateaction/index_pt.htm, 2010.

[2] Inquérito ao Consumo de Energia no sector doméstico (ICED) "Survey on Energy Consumption, in Portuguese". National Institute of Statistics and General Directorate for Energy and Geology: Lisbon, 2010.

[3] EPA ESPM (Energy Star Portfolio Manager), "Greenhouse Gas Inventory and Tracking in Portfolio", 2009.

[4] H. Haydock, J.-A. Arbon, "Study on energy performance of building", Report No: SIP/A/ITRE/ST/2008-10, manuscript completed in February, 2009, pp.107.

[5] A.M. Papadopoulous, E. Giama, "Environmental performance evaluation of thermal insulation materials and its impact on the building", International Journal for Building and Environment, Vol. 42, 2007, pp. 2178–2187.

[6] C. Du Plessis, "Agenda 21 for Sustainable Construction in Developing Countries", CSIR Report BOU/E0204. Pretoria: CSIR, CIB & UNEPIETC, 2002.

[7] J. Paiva. "Guia Técnico de Reabilitação Habitacional", Lisboa: INH e LNEC, 2006.

[8] T. Loga, N. Diefenbach (Eds.), Use of building typologies for energy performance assessment of national building stocks, existent experiences in European countries and common approach, First TABULA Synthesis Report, June 2010. Available from: www.buildingtypology.eu/downloads/public/docs/report/TABULA SR1.pdf.

[9] Euro construct, "Euro construct Country Report", 75th EUROCONSTRUCT Conference. Copenhagen, 13-14 June 2013. Copenhagen: Euro constructs, 2013.

[10] INE, 2013. Censos 2011. Lisboa: INE.

[11] F. Kuznik, D. David, K. Johannes, J. Roux, A review on phase change materials integrated in building walls, International Journal for Renewable and Sustainable Energy Reviews, Vol. 15, 2011, pp. 379–391.

[12] Lei 32/2012, 14 de Agosto," Regime Jurídico da Reabilitação Urbana". Lisboa: INCM, 2012.

[13] C.J. Kibert, & ICBR, "Sustainable Construction", Proceedings of the First International Conference of CIB TG 16. Tampa. November 6-9, 1994, Gainesville. CCE, M.E. Rinker Sr. School of Building Construction, College of Architecture, University of Florida, 1994.