Portugal SB07

Sustainable Construction

Materials and Practices

Challenge of the Industry for the New Millennium

edited by

Luís Bragança

Manuel Pinheiro

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Manuel Correia Guedes

Part 1

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IOS
Press

L. Bragança et al. (Eds.)
IOS Press, 2007

Foreword

The international conference "Portugal SB07: Sustainable Construction, Materials and Practices - Challenge of the Industry for the New Millennium" is organised in the scope of the International Initiative for Sustainable Built Environment (iiSBE). This event is supported by the Portuguese Presidency of the European Union during the second half of 2007 and by a range of international organisations such as CIB, UNEP, SD-MED and COST / European Science Foundation.

This international conference is part of the SB07 regional/national event series and as such constitutes also a preparation for the 2008 World Sustainable Building Conference to be held in September 2008 in Melbourne, Australia. The venue of this conference is also relevant, as it is the first international conference on this topic to be held in Portugal. The organisers hope that this initiative will promote further the sustainability of construction industry and the built environment, consequently, contributing to further sustainable development of Portugal and the other participating countries.

The construction industry is a vibrant and active industry representing approximately 10% of Portuguese GDP. The building sector is responsible for creating, modifying and improving the living environment of humanity. On the other hand, construction and buildings have considerable environmental impacts, consuming a significant proportion of limited resources of the planet including energy, raw material, water and land. Therefore, the sustainability of the built environment, the construction industry and the related activities is a pressing issue facing all stakeholders in order to promote Sustainable Development.

The new millennium is challenging practitioners and researchers with the sustainability of the built environment and the construction industry. Hence, the main purpose of this conference is to discuss these challenges and look for solutions that actively facilitate and promote the adoption of policies, methods and tools to accelerate the movement towards a global sustainable built environment.

The intention of the organizers is to give an opportunity to practitioners, academics, scientists, engineers, architects, contractors, manufacturers, owners and users from all over the world to come together in a pleasant location to discuss recent developments in the field of sustainable construction, materials, practices and construction sustainability assessment.

The conference main topics cover a wide range of up-to-date issues and the contributions received from the delegates reflect critical research and the best available practices in the Sustainable Construction field. The issues presented include:

- Building sustainability assessment tools
- Indoor environment quality and benchmarks
- Sustainable resources and materials use
- Use of non-conventional materials
- Use of industrial waste
- Eco-materials and technologies
- Sustainable management of existing building stock
- Innovative sustainable construction systems
- Design for climate change
- Design and technologies for energy efficiency and conservation
- Design for minimizing and using construction and demolition waste
- Design for service-life
- Design for deconstruction

- Design for flexibility
- Use of IT in design
- Closing the loop
- Actions and policies to implement sustainable construction
- Designing the sustainable city of tomorrow and Urban Sustainability
- Planning aspects for sustainable construction (construction site, procurement and commissioning)
- Integrated decision making process
- Biomimicry and design with nature
- Teaching sustainable construction
- Case Studies

All the papers selected for presentation at the conference and published in these Proceedings, went through a refereed review process and were evaluated by, at least, two reviewers.

We want to thank all the authors who have contributed papers for publication in the proceedings. We are also grateful to the reviewers, whose effort and hard work secured the high quality of papers expected for this conference. Their efforts reflect their commitment and dedication to Science and Sustainable Construction.

We want to thank the support given by InCI (Instituto da Construção e do Imobiliário) that sponsored and made possible the international edition of these Proceedings.

Finally, we want to address a special thank to iiSBE, CIB, UNEP, Ordem dos Engenheiros and SD-MED and wish great success for all the other SB07 events that are taking place all over the world.

The Organizing Committee and Proceedings Editors

Luis Bragança (University of Minho)
Manuel Pinheiro (Instituto Superior Técnico)
Said Jalali (University of Minho)
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INSTITUTO DA CONSTRUÇÃO E DO IMOBILIÁRIO

Welcome

The strategy defined by the Portuguese Government for construction and real estate is based in sustainable concepts, optimizing the State regulatory functions in view to reduce bureaucracy, improve processes transparency, strengthening cooperation and guarantying an effective co-ordination in the definition and implementation of Government Program policies.

As a result of the above mentioned strategy, the Portuguese Government recently assigned a new mission and new challenges to InCI - Instituto da Construção e do Imobiliário, I.P. (Institute of Construction and Real Estate).

The mission of InCI, I.P. comprehends the regulation of the construction and real estate markets being the new challenges the promotion and implementation of solutions that achieve sustainability priorities, reduce environmental impact, enable energy efficiency in buildings, contribute to energy and environment certification, improve the rational use of materials and the construction waste management in Portugal. Summarizing, InCI, I.P. has an ambitious and challenging aim that is the modernization of the Portuguese construction sector contributing to the efficiency and sustainability of construction in general and of buildings in particular.

The aims of InCI, I.P. are fully in line with the scope of the conference "Portugal SB07: Sustainable Construction, Materials and Practices - Challenge of the Industry for the New Millennium" and, therefore, participating in the edition of these Proceedings is a contribution to positively changing the construction industry towards the adoption of sustainable and efficient building practices.

InCI's support will also promote the opportunity to increase awareness and interest among the economic operators to the issues related to sustainable construction, through the exchange of practices, experiences and information.

It is with a great pleasure that InCI, I.P. warmly welcomes all the participants and wishes a great success to the Conference Portugal SB07.

The Executive Board

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The Calculation Model of the New Portuguese Thermal Regulation – put side by side with Dynamic Simulation

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ABSTRACT: Nowadays, there is a global urge to reduce the energy consumption, in order to slow down the environmental pollution. Since the building sector is one of the main energy consumers in Portugal, there is a great pressure for enhancing the energy efficiency in this sector. Currently the measure with more potential to effectively reduce the buildings energy consumption is the new Portuguese thermal regulation. However, to guarantee a good performance in reducing the energy consumption, the thermal regulation must present a good precision in the heating and cooling needs estimation. Therefore, the calculation model of this regulation was evaluated in relation to a dynamic simulation tool - VisualDOE. This evaluation was carried out applying both estimation methods to the Test Cells built in the School of Engineering of the University of Minho and the results obtained demonstrated a good performance of the thermal regulation.

1 INTRODUCTION

One of the main challenges that nowadays humankind has to face is the climatic changes and environmental depletion. It is known that these challenges are closely related to the energy consumption. In the 15 European Union, there are about 164 million buildings, responsible for 40% of the final energy demand and 1/3 of the greenhouse gas emissions. So, in order to promote the reduction of energy consumption, it is fundamental to apply sustainable development principles in the construction sector (Tzikopoulos et al, 2005; Eyckmans and Cornillie, 2002).

There are several measures that can be applied in order to reduce the buildings energy consumption, since the appeal of the consumers consciousness to the environmental problems, to the development of new construction solutions more energy efficient.

However, one of the measures with a larger impact in building energy consumptions is the implementation of more restrictive thermal regulation. The new Portuguese thermal regulation – Regulation of the Characteristics of the Thermal Behavior of Buildings (RCCTE) – increases the minimum requirements, promote the use of renewable energy and support the use of certified materials.

The driving force of the thermal regulation revision was the European Energy Performance of Buildings Directive (European Commission, 2003). The main objectives of the EPBD are the harmonization of all thermal regulations in the European Union and the increase of buildings energy performance, taking in account the climatic conditions, interior comfort of the occupants and economic viability, for both new buildings and existing buildings.

In order to be efficient and effective, the thermal regulation must correctly estimate the energy performance of buildings. Having this fact in mind the RCCTE calculation model was put side by side with the dynamic simulation for the energy performance estimation.

The case study was the heating and cooling needs estimation of the Test Cells built in the School of Engineering of the University of Minho, using the RCCTE calculation model and the dynamic simulation tool VisualDOE.

2 BUILDING DISCRIPTION

The Test Cells applied in this study are formed by a Sustainable Test Cell (STC), a Conventional Test Cell (CTC) and a Passys Test Cell (PTC). This study focuses on STC and CTC, in order to guarantee that the RCCTE can estimate with good accuracy conventional solutions and also non-conventional solutions.

2.1 *Sustainable Test Cell*

The Sustainable Test Cell (STC) contains two rooms:

- Room 1 (simulates a bedroom) – It was constructed using compacted earth walls (Goodhew & Griffiths, 2005) and an opening in the south façade. The high thermal inertia combined with an opening equipped with exterior horizontal and vertical shading devices to avoid overheating in the summer. In order to improve the sustainability of the solution the exterior walls of this room were built with a locally available material - Earth;
- Room 2 (simulates an office) – It is an insulated lightweight construction with a large opening in the north façade to promote daylightning and thus reduce the energy spent in lightning.

Between the two rooms of this Test Cell there is a movable partition that allows testing the performance of this Test Cell as a whole or as being constituted by two distinct rooms (Silva, 2006).

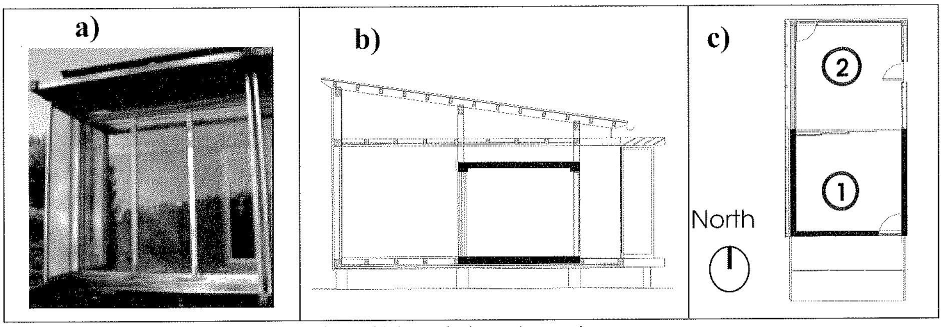

Figure 1. Sustainable Test Cell: a) Photo; b) lateral view; c) top view.

2.2 *Conventional Test Cell*

The Conventional Test Cell (CTC), shown in Fig. 2, contains three rooms: the room 1 simulates a bedroom; room 2 simulates a bathroom; room 3 simulates a hall. The CTC was built with a double pane hollow brick envelope wall with insulation on the air gap. This Test Cell represents the conventional Portuguese Construction (Mendonça, 2003).

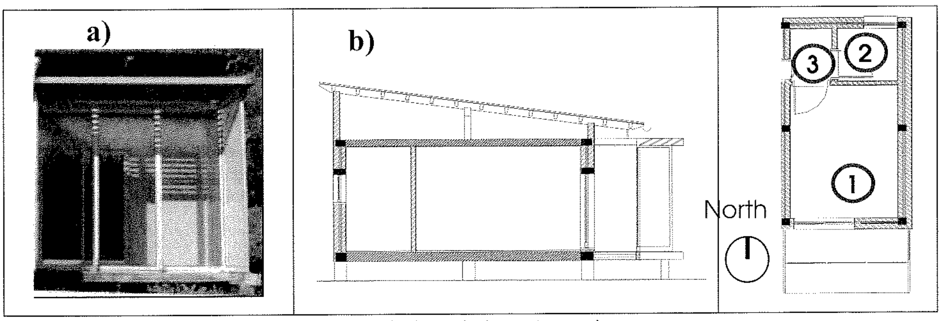

Figure 2. Conventional Test Cell: a) Photo; b) lateral view; c) top view.

3 ESTIMATION METHODS

3.1 *RCCTE*

The new Portuguese thermal regulation focuses residential buildings and service building without HVAC systems. One of the main updates in this regulation was due to the recent higher comfort required by the occupants, especially in terms of cooling demands. Then, the objectives of this regulation are: Guarantee that the heating and cooling requirements for thermal comfort, the ventilation requirements for air quality and the hot water requirements are satisfied without an excessive energy consumption; Minimize the pathologies in the construction elements due to condensation. The main updates in this regulation where (RCCTE, 2006):

- New climatic zoning;
- Interior comfort set points – Winter (20°C); Summer (25°C + 50% RH);
- Minimum air changes per hour – 0.6;
- Domestic Hot Water (DHW) reference consumption – 40 l at 60°C per person and per day;
- New methodology for thermal bridges calculation;
- Heating needs methodology reviewed;
- New Cooling needs methodology;

This regulation defines reference values for the *primary energy global needs* (*Nt*) in order to limit the *specific nominal primary energy annual global needs* (*Ntc*). So, the *Ntc* value cannot be higher than the *Nt* value. The Nt and Ntc are obtained using the following equations:

$$Nt = 0{,}9.(0{,}01.Ni + 0{,}01.Nv + 0{,}15.Na)\ (kgep/m^2.year) \quad (1)$$

Where *Ni, Nv, Na* are the heating, cooling and DHW reference needs, respectively.

$$Ntc = 0{,}1.(Nic/\eta i).Fpui + 0{,}1.(Nvc/\eta v).Fpuv + Nac.Fpua\ \ (kgep/m^2.year) \quad (2)$$

Where *Ni, Nv* are the heating and cooling system efficiencies, respectively; *Nic, Nvc, Nac* are the heating, cooling and DHW specific needs, respectively; *Fpui, Fpuv, Fpua* are the weighting factors for the heating, cooling and DHW needs, respectively.

3.2 *VisualDOE*

VisualDOE is a Windows™ application that can estimate the energetic performance of buildings. The calculation engine used in this tool is the, very well known and tested, DOE2.1E. However, only the 3rd version of this tool (VisualDOE 3.1) can be considered as a Graphical User Interface of the DOE engine, as it allows a good control of the introduction of geometrical elements, in real-time, thru the visualisation of the model produced by the tool and it has the possibility to edit the model by simply clicking with the mouse in a element. This tool can be used without any knowledge of the source engine (Green Design Tools, 2001).

For estimate the buildings energy performance with VisualDOE it is necessary to follow 3 steps:

- Project data introduction;
- Execution of the simulation;
- Results analysis.

The project data introduction begins with the definition of all the VisualDOE databases with the elements applied in the building – Glazing, Openings, Materials, Constructions, Occupancy, Schedules and Utility rates – and afterwards the introduction of the model and project data that is formed by 6 folders – Project, Blocks, Rooms, Façade, Systems, Zones. As VisualDOE was created for the Windows™ platform, the databases are easily updated with new material and constructions thru a graphical interface, as shown in Figure 3.

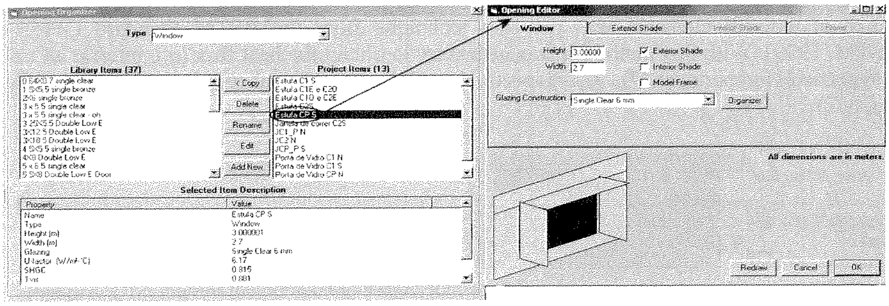

Figure 3. Openings definition in VisualDOE databases.

In the 2nd step there will be present three folders – Simulation, Standard DOE-2 Reports and Hourly Reports – where the user can define the base case, the alternatives (if necessary) and all the reports needed (hourly, daily, monthly or yearly results) for each specific study.

For the results analysis there are two main groups of data – the VisualDOE graphs and reports and the DOE-2 reports. The main difference between these sets of results is that the ones obtained by VisualDOE follow the Windows™ platform (allows exporting results to other tools) while the DOE-2 reports follow a DOS platform.

3.3 *Model Calibration*

To guarantee a good accuracy of the model, it is necessary to calibrate it, adjusting the model to the reality. In this Case Study the calibration was possible due to the existence of a measurement system in the Test Cells and it was carried out in three main steps (Silva et al, 2006):

- Obtaining a climatic file that represent the climatic conditions which the Test Cells were exposed;
- Obtaining the "in-situ" thermal resistance of the exterior walls;
- Comparing the interior temperature, measured "in situ" with the interior temperature calculated by VisualDOE.

Climatic File – For this case study the climatic file was obtained using the data retrieved from the weather station installed in the Test Cells. However, in addition to the parameters directly obtained by the weather station it was necessary to calculate more parameters (underlined in Table 1) using the ones obtained "*in-situ*" (ASHRAE, 1997; Buhl, 1999; ISQ, 2000; Krieder and Rabl, 1994).

Table 1. VisualDOE required climatic data.

"In-Situ" Parameters	Required Parameters	Obtained from:
1) Temperature	Dry bulb Temperature	1)
2) Relative Humidity	Wet bulb Temperature	1); 2)
3) Precipitation	Humidity Ratio	1; 2)
4) Wind Direction	Enthalpy	1); 2)
5) Wind Speed	Precipitation	3)
	Wind Direction	4)
6) Total Horizontal Solar Radiation	Wind Speed	5)
	Total Horizontal Solar Radiation	6)
	Direct Solar Radiation	6)
	Clarity ratio	6)

"In-situ" thermal resistance – The method used for the calculation of the "*in-situ*" thermal resistance of exterior elements was the sum technique from the ASTM Standard C1155–95 (ASTM, 1999). With this method it was necessary to obtain the heat flux (q_i), interior an exterior superficial temperature (T_{is}, T_{es}, respectively). Then, the thermal resistance is obtained by the Equation 3:

$$R_e = \frac{\sum_{k=1}^{M} \Delta T_{Sk}}{\sum_{k=1}^{M} q_{ik}} \qquad (3)$$

However, to guarantee a good performance of the calculation it is necessary to execute a convergence test (CR_n), where two consecutive time intervals must have a convergence lower than 0.1, and a variance test [$V(R_e)$] where the variance must be lower than 10%.

The thermal resistances of the Test Cell elements identified in Figure 4 were obtained by the use of this technique and the respective values are:

Wall A – Compacted earth, 15 cm; *Thermal Resistance* - **0.34** $m^2.°C/W$;

Wall B – Agglomerated board (concrete / wood), 1.2 cm + Air layer, 4 cm + Expanded cork insulation, 5 cm + Compacted earth, 15 cm; *Thermal Resistance* - **2.97** $m^2.°C/W$;

Wall C – Agglomerated board (concrete / wood), 1.2 cm + Air layer, 6 cm + Agglomerated board (concrete / wood), 1.9 cm + Expanded cork insulation, 8 cm + Coconut fiber insulation, 2 cm + Carton / plaster gypsum board, 1.3 cm; *Thermal Resistance* - **1.04** $m^2.°C/W$;

Wall D – Stucco, 2cm + Hollow brick, 11 cm + Air layer, 4 cm + Extruded Polystyrene insulation, 4 cm + Hollow brick, 15 cm + Stucco, 2cm; *Thermal Resistance* - **0.34** $m^2.°C/W$.

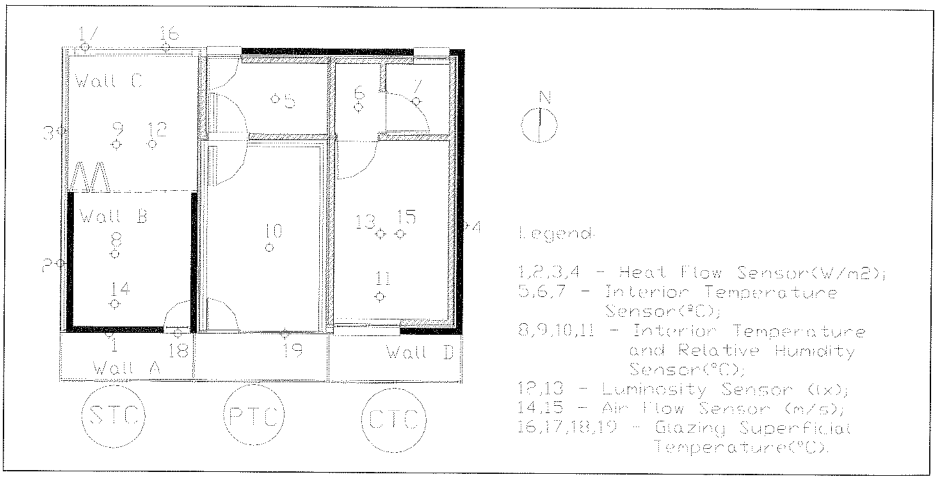

Figure 4. Distribution of sensors inside the Test Cells.

"In-Situ" temperature Vs VisualDOE calculated temperature – This procedure is very useful for making the last adjustments of the model, being possible the detection of some inaccuracy in the model as well as adjusting the thermal inertia. In Figure 5 it is possible to observe the results from the model adjustments.

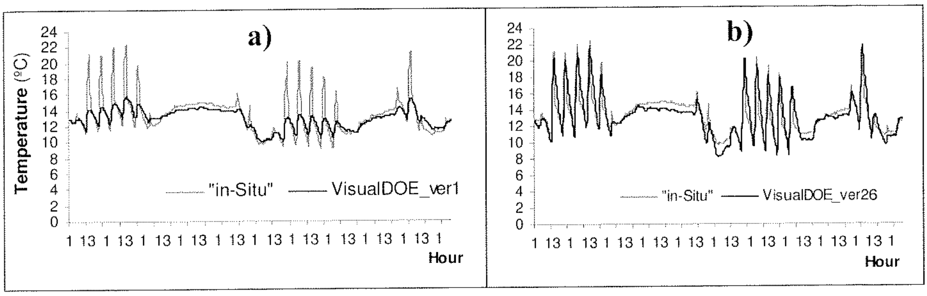

Figure 5. CTC interior temperature in VisualDOE model: a) before calibration; b) after calibration.

After the model calibration, the average error of the model was tested comparing the "*in-situ*" measured Test Cells interior temperature with the VisualDOE results, for the whole period of the simulation – October 2003 to October 2004. Between October 2003 and February 2004, the Test Cells were not equipped with the Sunspace (built in March 2004), and thus the model of the Test Cells without sunspace was tested for an average error between October 2003 and February 2004. The model with sunspace was tested for the remaining period.

The average error of the model without sunspace is of 8% and for the model with sunspace is of 4.8%. Taking into consideration that the obtained average errors are relatively small and that the calibration was performed for one year of "*in-situ*" measurements, the achieved results assure that the application of VisualDOE is representative and thus it is possible to use it to test the energetic performance of the Test Cells.

4 RESULTS

4.1 *RCCTE*

To achieve better results using the simplified model RCCTE, was necessary to calibrate some parameters specifically to this case study. Then, the Degree-Days, the average monthly solar energy and the summer average temperature, were calculated from the Test Cells weather station data instead of using the standard values tabulated in the thermal regulation.

Also, for the walls to which the "*in-situ*" thermal resistance was calculated the respective values were applied in the RCCTE.

Following the thermal regulation methodology to the CTC and the PTC it was obtained the result shown in Table2.

Table 2. Heating and Cooling need from RCCTE.

Test Cells		Heating Needs	Cooling Needs (kwh/m^2.year)	Total Needs
With Sunspace	STC	127.7	49.5	177.2
	CTC	100.9	13.8	114.7
Without Sunspace	STC	139.8	51.3	191.1
	CTC	129.4	30.3	159.7

4.2 *VisualDOE*

After the calibration of the Test Cells model, the entire project data was inserted in VisualDOE and a "warming" simulation was carried out being created an Input file to the DOE-2 calculation model. This Input file was modified to allow the introduction of all the particularities of the Test Cell, as the introduction of some construction materials, the modification of some construction elements in the interior walls, floors and roofs, the definition of the sunspaces, the modification of the thermal inertia. Then, the Test Cells VisualDOE final model (Figure 6) was created and became ready to be used.

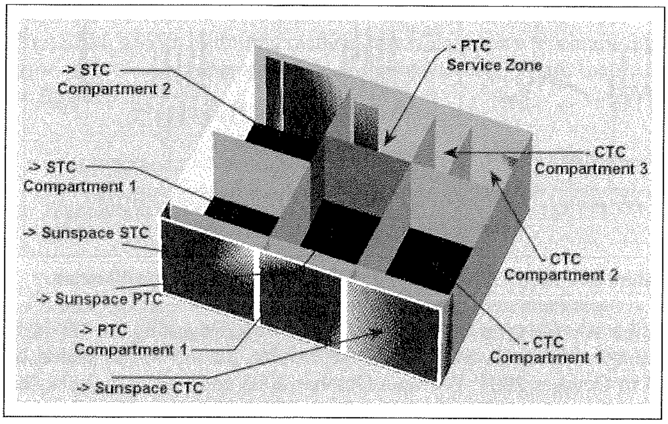

Figure 6. Model of the Test Cells.

In order to run the final simulation, it was inserted the final model in VisualDOE and defined a HVAC system with the heating and cooling setpoints as established in RCCTE – 20ºC for heating and 25ºC and 50% RH for cooling. For the final reports it was selected the hourly energy consumption spent by the HVAC system. The results obtained are presented in Table 3.

Table 3. Heating and Cooling need from VisualDOE.

Test Cells		Heating Needs	Cooling Needs (kwh/m^2.year)	Total Needs
With Sunspace	STC	124.7	41.9	166.6
	CTC	120.5	13.6	134.1
Without Sunspace	STC	135.2	42.5	177.7
	CTC	149.8	32.3	182.1

4.3 *RCCTE Vs VisualDOE*

In order to test the precision of the RCCTE calculation methodology the results obtained where compared with the ones obtained by VisualDOE (the heating and cooling needs obtained from VisualDOE were calculated only for the periods defined in RCCTE as heating season and cooling season). The differences between the two estimation methods are presented in Table 4.

Table 4. Difference between RCCTE and VisualDOE estimation.

Test Cells		Heating Needs	Cooling Needs Differences (kwh/m^2.year)	Total Needs
With Sunspace	STC	3	7.6	10.6
	CTC	19.6	0.2	19.4
Without Sunspace	STC	4.6	8.8	13.4
	CTC	20.4	2	22.4

From Table 4 it can be concluded that there is an unexpected very high convergence between the STC total needs estimated by RCCTE and by VisualDOE, with only an average variance of 6.5% in the total needs. This fact is due to the good calculation methodology adopted by RCCTE in association with the accurate calibration of the models. The higher variation in the estimation of CTC total needs, 13.4%, is due to the heating needs part. This fact can be explained by a higher south oriented glazing area in this Test Cell that can lead to very high solar radiation entering the building. This inaccuracy can lead to an overestimation of the thermal gains in the RCCTE methodology.

5 CONCLUSIONS

The objective of this study was to evaluate the precision of the new Portuguese thermal regulation calculation methodology. Therefore, the RCCTE heating and cooling needs estimation was put side by side with the ones calculated with the dynamic simulation tool VisualDOE.

From this evaluation it can be said that the RCCTE calculation methodology have a better precision than what was expected, as it is a simple method based in the Degree-Day method. This method just appears to have a higher difficulty in estimate accurately the heating needs for buildings with large openings.

Then it can be assumed that this new regulation can estimate the buildings energy needs accurately and thus it can be used as a simplified tool to evaluate the energy efficiency of buildings.

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