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Natural illumination availability in Ponte da Pedra apartment block – a case study

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ABSTRACT: This paper presents the results of the in-situ measurements of the natural illumination availability in the Ponte da Pedra apartments block. These measurements were carried out in order to meet the SHE (Sustainable Housing in Europe) project requirements. This paper also presents a comparative analysis of the natural illumination environmental conditions of one of the apartments in this building, by using two simulation tools to predict natural illumination availability: "Ecotect" and "Desktop Radiance". The results obtained with these tools were also compared with the "in situ" measurements, in order to show that simple and user-friendly software tools can be a good basis to evaluate the real natural illumination conditions in the practise of a building project.

1 INTRODUCTION

Daylight is playing a significant role in achieving quality of life and comfort in buildings. There are ample evidence that access to windows affect mood motivation and productivity at work, through reduced fatigue and stress (Tabet & Shelley, 2003). Daylight can also provide economic benefits by dimming down or switching off electric lights. Recognized such importance, an urbanization located in Ponte da Pedra, Porto, implemented some strategies regarding the improvement of natural illumination conditions.

Some measurements were carried out in order to characterize the "in situ" daylight availability. This characterization was based on a quantitative evaluation of the natural illumination conditions, through the assessment of the Daylight Factor (DF), calculated considering the simultaneously measured values of the interior and exterior illuminance levels.

2 METHODOLOGY

For this study, some "in situ" measurements were taken in order to evaluate the daylight availability of the apartments block under study. The measurements were carried out on winter days, in different apartments at different heights and for three types of rooms (kitchens, bedrooms and living rooms) with different geometries and window-openings, under conditions similar to an overcast sky (Batsford, 1992). The "in situ" values were also compared with those obtained with two simulation tools in order to assess which of them lead to better results.

The parameter considered for this study was the Daylight Factor calculated through an alternative method (Santos, 2001) by the following expression (1):

$$DF(\%) = \frac{\sum E\,\text{int}}{\sum Eext} \times 0.396 \times 100 \qquad (1)$$

Where Eint = internal horizontal illuminance; Evext = External Horizontal illuminance.

This expression is used when the exterior sensor illuminance is placed in a vertical line. For the calculation of the Daylight Factor, there were needed two illuminance sensors, as it can be seen in Figure 1, one placed inside the room and the other placed on the centre of the window glass. On the outside of the window, an obstruction element was placed at the bottom of the window (see Figure 1) in order to avoid that the reflected light by the ground hit the sensor.

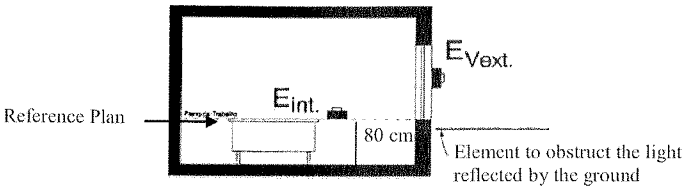


Figure 1 – Method of measurement of the illuminance levels

The illuminance levels in the rooms were measured, around 12:00 h (solar time), in a horizontal level, 80 cm above the floor, on a square grid with points equally spaced of 50 cm.

3 DESCRIPTION OF THE CASE STUDY

The measurements campaign, in order to evaluate the daylight availability inside the building, was carried out in several apartments, in lot number 8 (see Figure 2 below), at different levels. This building is an apartment block located in Ponte da Pedra (latitude 41.17 and longitude -8.37). The building is located in an area without significant obstructions.

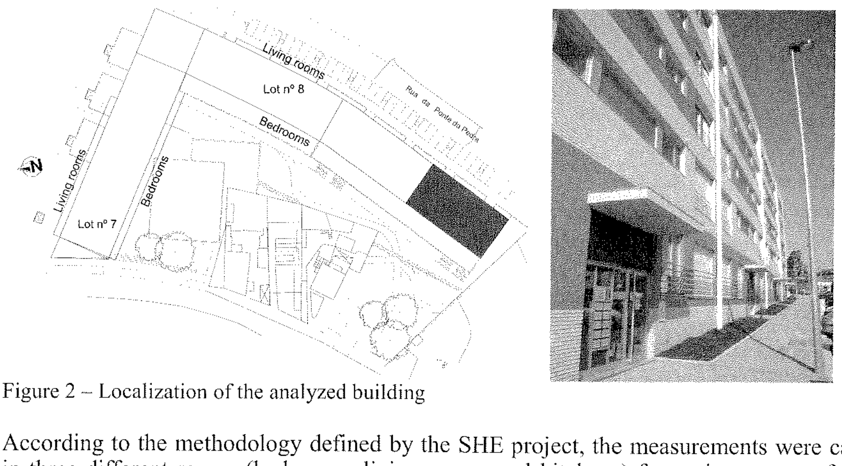
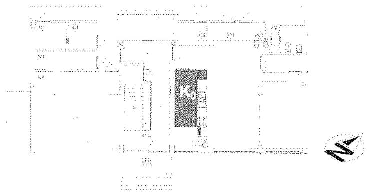
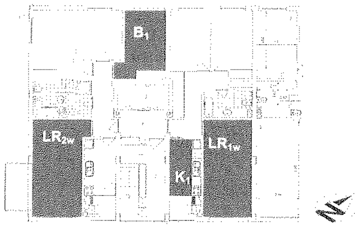


Figure 2 – Localization of the analyzed building

According to the methodology defined by the SHE project, the measurements were carried out in three different rooms (bedrooms, living rooms and kitchens) for various types of windows. The analyzed compartments are identified and shown in Figure 3.



K0 – Kitchen on the ground floor, south-west oriented

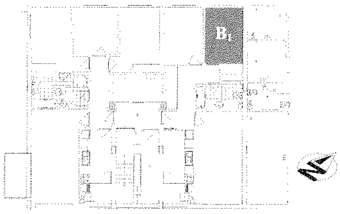


K1 – Kitchen on the 1st floor, south-west oriented

B1 – Bedroom on the 1st floor, south-east oriented

LR1w – Living Room with two windows, on the 1st floor, south-west oriented

LR2w – Living Room with one Window, on the 1st floor, south-west oriented



B3 – Bedroom on the 3rd floor, north-east oriented

Figure 3 – Identification of the selected rooms used for the daylight availability assessment

Tables 1 and 2 show a list of the characteristics of the different indoor surfaces and windows.

Table 1 – Reflectance properties of the indoor surfaces (Santos, 2001)

Interior Surface	Colour	Texture	Condition	Reflectance (%)
Wall (bedroom)	Clear - yellow	wall plaster smooth	clean	76
Wall (living room)	Clear - yellow	wall plaster smooth	clean	76
Wall (kitchen)	White	glazed	clean	60
Ceilings (bedroom)	White	wall plaster smooth	clean	86
Ceilings (living room)	White	wall plaster smooth	clean	86
Ceilings (kitchen)	White	wall plaster smooth	clean	86
Floor (bedroom)	Clear - brown	Wood polished	clean	30
Floor (living room)	Clear - brown	Wood polished	clean	30
Floor (kitchens)	Dark - grey	Wood polished	clean	10
Furniture and door (bedrooms)	Clear - brown	Wood polished	clean	48
Furniture (living room)	Yellowish-brown	Wood polished	clean	48
Furniture (kitchen)	Dark - Blue	Vinyl smooth	clean	15

Table 2 - Properties of the Windows Openings (Saint Gobain, 2000)

Interior Surface	Colour	Texture	Condition	Transmittance (%)	Sc *
Double Glass (bedroom)	transparent	smooth	clean	81	0.87
Double Glass (living room)	transparent	smooth	clean	81	0.87
Double Glass (kitchen)	transparent	smooth	clean	81	0.87
Simple Glass (kitchen)	transparent	smooth	clean	90	0.98

*Sc- Shading Coefficient

4 REFERENCE VALUES

Table 3 shows a list of the recommended values of the Daylight Factor, for the three types of rooms studied (kitchens, bedrooms and living rooms).

Table 3- Recommended values of the Daylight Factor

Rooms	DF (%)*
Bedrooms	≥ 0.5 % at 3/4 of the compartment length
kitchens	≥ 2 % at 1/2 of the compartment length
Living rooms	≥ 1 % at 1/2 of the compartment length

*Values recommend by the Commission of the European Communities

5 SIMULATION TOOLS

For the comparative analysis, two of the most well-known simulation tools of natural illumination availability were selected: "Ecotect" and "Desktop Radiance". The real conditions were recreated in these programmes and simulated results were produced in order to be compared with the real ones.

5.1 "Ecotect"

The original "Ecotect" software was written and presented in a PhD thesis by Dr. Andrew Marsh at the School of Architecture and Fine Arts at The University of Western Australia. Since then, the software has undergone some major changes. Version 2.5 was the first commercial release in 1997. Version 5.2 builds significantly on the functionality of previous versions introducing a range of new analysis functions and sketch visualization.

The "Ecotect" tool offers a range of lighting analysis options. Its main focus is on natural lighting analysis. However, it can also analyse rudimentary artificial lighting design. "Ecotect" implements the Building Research Establishments (BRE) split flux method for determining the natural light levels at points within a model. This is based on the Daylight Factor concept. The Daylight Factor is a ratio of the illuminance at a particular point within an enclosure to the simultaneous unobstructed outdoor illuminance.

The basic analysis of natural illumination uses two types of corresponding definite skies as darkened and uniform to the models normalized for the Commission International of l'Eclairage (CIE). The geometric data of the place to analyse must be filled in. They are indicated by the coordinates of latitude and longitude as well as the orientation of the building. The results can be presented numerically (tables) and graphically as distinct formats: curves iso-lux.

5.2 "Desktop Radiance"

This program was developed by the department of technologies of buildings of the National Laboratory Lawrence Berkeley, California, United States.

Desktop radiance is a design tool that facilitates the design and analysis of buildings to optimize the efficiency of day lighting systems and lighting technologies. Desktop Radiance is a plug-in module that works with other popular computer aided design tools (CAD) to provide the user interaction and 3D modelling capabilities. Once created the 3D model, it can be detailed by using the Desktop Radiance library of materials, glazing, luminaries and furniture. As soon as the model is complete, the analysis parameters such as camera views or reference point calculations, building orientation and zone of interest has to be defined.

For the illumination analysis, the program uses a database with the geometric coordinates, timetable zones and some atmospheric data for some locations. The user is able to improve this database.

The "desktop radiance" tool allows presenting the data in tables and graphics through the analysis of images with the following options: levels of illumination directly on the image, iso-lux curves and FLD and levels of colours associated to the values of illuminance and luminances. Moreover, the program uses an interesting characteristic to filter the processed images and takes into account the sensitivity of the human eye.

6 RESULTS

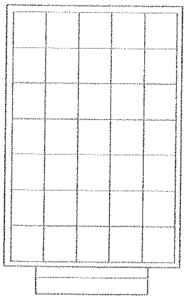
In both programs, the properties of the materials used are described in Tables 2 and 3.

The obtained results for the overcast sky conditions, both by simulations and by "in situ" measurements, are shown in tables 4 to 10.

Table 4 shows the values of the exterior illuminances obtained "in situ" and with the two simulation programs.

Table 4 – Mean external horizontal illuminance

Room	External Horizontal Illuminance (E_{ext})		
	"In situ"	"Ecotect"	"Desktop Radiance"
B1 – Bedroom on the 1st floor	13 555	7703	13599
B3 – Bedroom on the 3rd floor	13 704	7703	13555
LR2w – Living room on the 1st floor	13 207	7703	13205
LR1w – Living room on the 1st floor	13 710	7703	12506
K0 – Kitchen on the ground floor	12 385	7703	12605
K1 – Kitchen on the 1st floor	13 716	7703	12385



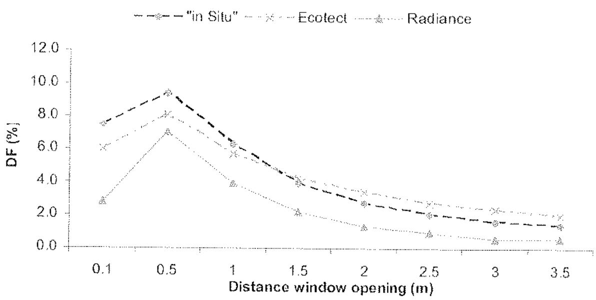


Figure 4 – Measurement grid and DF values for the bedroom on the 1st floor

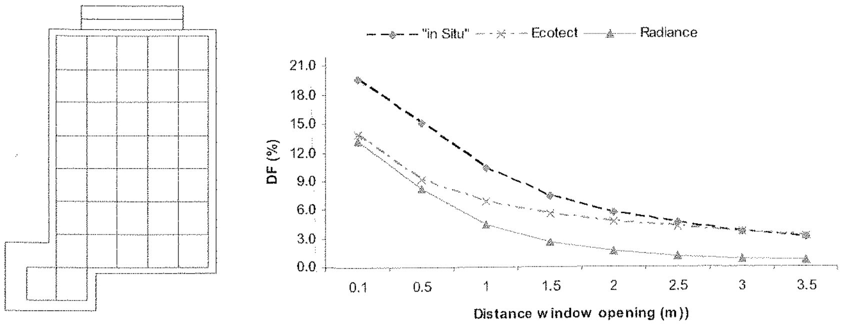


Figure 5 – Measurement grid and DF values for the bedroom on the 3rd floor

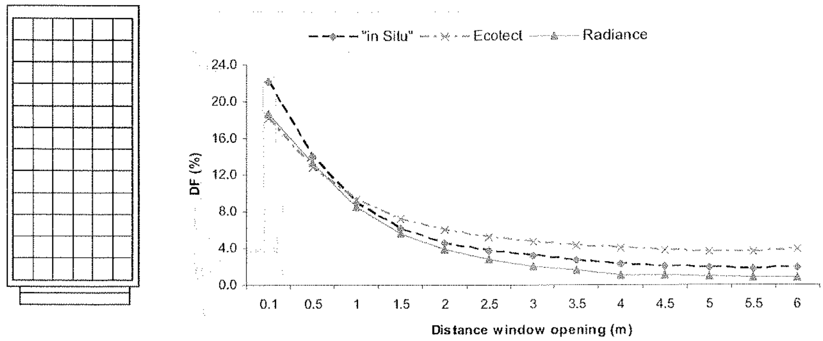


Figure 6 – Measurement grid and DF values for the Living room with one window

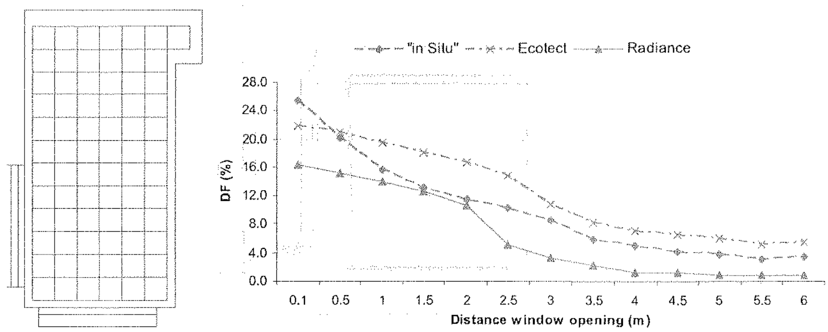


Figure 7 – Measurement grid and DF values for the bedroom on the 1st floor

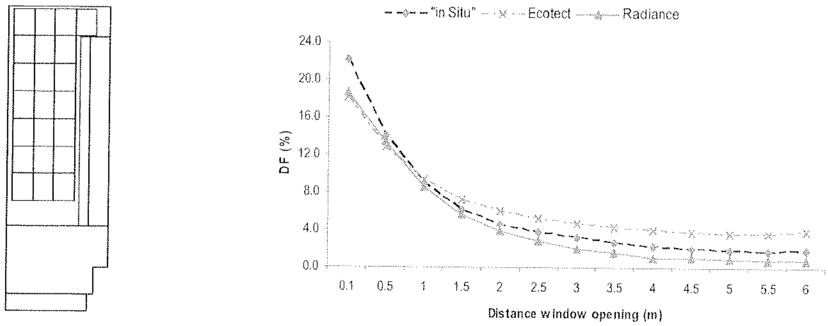


Figure 8 – Measurement grid and DF values for ground floor kitchen

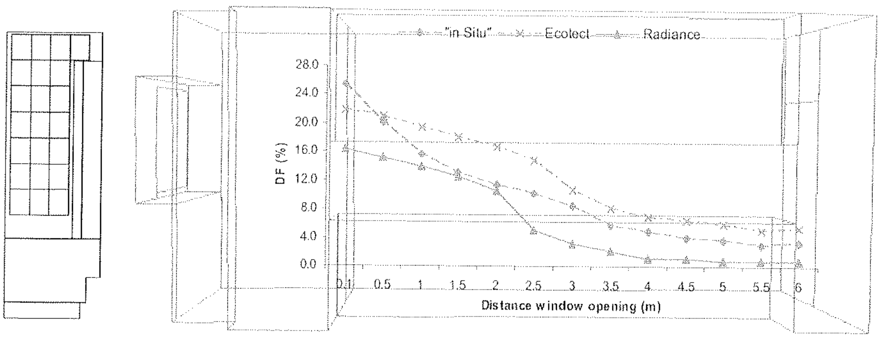


Figure 9 – Measurement grid and DF values for the kitchen on the 1st floor

Table 4 shows that the measured outside values of illuminance are similar to the ones obtained with "Desktop Radiance" but different from those obtained with "Ecotect". In any case, both simulated values follow the outside illuminance values:

E measured-outside / E measured-outside "Ecotect" = 1.7
E measured-outside / E measured-outside "Desktop Radiance" = 1

Table 5 presents the evaluation of the Daylight Factor in the studied rooms.

Table 5 – Evaluation of the Daylight Factor in the studied rooms

Room	DF (%) Recommended	DF (%) "in Situ"	DF (%) "Ecotect"	DF (%) "Desktop Radiance"
B1 – Bedroom on the 1st floor	≥ 0.5 % at 3/4 length	3.70	3.60	0.80
B3 – Bedroom on the 3rd floor	≥ 0.5 % at 3/4 length	1.70	2.30	0.50
LR2w – Living room on the 1st floor	≥ 1 % at 1/2 length	8.30	10.10	3.10
LR1w – Living room on the 1st floor	≥ 1 % at 1/2 length	3.10	4.60	1.90
K0 – Kitchen on the ground floor	≥ 2 % at 1/2 length	0.49	0.93	0.36
K1 – Kitchen on the 1st floor	≥ 2 % at 1/2 length	0.54	0.64	0.42

It is possible to observe that the daylight availability is good, satisfying the recommended values, in all living rooms and bedrooms. However, the kitchens do not meet the requirements. The main reasons for this fact are the dark colours of the pavements and furniture as well as the not favourable geometry of the windows and of these rooms.

It is also possible to see that, considering similar conditions, the "in situ" measurements show differences when compared with the values obtained by simulation for the illuminance values registered inside the rooms. It was observed the following ratio:

E measured-inside / E measured- inside "Ecotect" = 0.92
E measured- inside / E measured- inside "Desktop Radiance" = 1.68

The values listed in table 5 show that "Ecotect" usually lead to higher values of DF while "Desktop Radiance" lead to lower levels of this factor. In general, the real values are situated between the simulated values obtained with the two tools, as can be seen in figures 4 to 8. It is also possible to see that as the distance to the window increases, the deviation of the "Ecotect" values from the real values also increases.

7 CONCLUSIONS

Trough the "in situ" evaluation, as well as through the simulation tools, it is possible to conclude that only the kitchens do not accomplish the recommended values of DF.

In Portugal, statistic values for outside illuminances, by locality, do not exist, but they do not constitute a real difficulty on DF calculation with "Ecotect". The same is not true on the calculation of inside illuminance. This way, using "Ecotect" is necessary to introduce the adequate outside illuminance value for each region in order to not make evaluation mistakes of inside illuminance.

Although the outside illuminance values obtained with "Ecotect" are very different from the real ones, it should be kept in mind that this value depends on the place latitude and do not affect the inside DF value obtained in the room evaluation.

From the comparison of the real values with the simulated ones, it is possible to conclude that "Ecotect" tool lead to better results than "Radiance Desktop" tool. However, the use of these tools can be a priceless assistance on the choice of solutions that benefit the project in terms of luminic comfort, contributing in this way to the building sustainability.

8 BIBLIOGRAPHY

Batsford, Commission of the European Communities; Energy conscious design, a primer for Architect,Pub B.T. Batsford Ltd, 4 Fitzhardinge street, London W1HOAH, 1992.

Santos, A.J. – Desenvolvimento de uma metodologia de caracterização das condições de iluminação natural nos edifícios baseado na avaliação "in SITU"; Sector de edições e Artes Gráficas do LNEC, Lisboa, 2001.

SHE project - Sustainable Housing in Europe - European demonstration project funded within the 5th FP -Energy, Environment and Sustainable Development, Key Action 4 - Cities of the Future and Cultural Heritage (March 2003 œ February 2008).

Tabet, Kheira. & Shelley, Gary. "An investigation on the effect of access to windows on visual comfort, motivation and productivity. 3rd European Conference on Architecture, Florence, Italy. 17-21 May ,2003.

Manual do vidro – Saint Gobain, Ed. 2000.