LARGE OFFICE BUILDINGS, WHAT ARE THE DOMINANT PARAMETERS FOR ENERGY CONSUMPTION?

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ABSTRACT The thermal behaviour of an office building is presented and discussed, as well as the results of a sensitivity study, which analyses the impact of architectural decisions and the effect of occupancy in terms of energy consumption (cooling and heating loads). This study was carried out using one floor of an office building, with large glazed facades, recently built in S. Paulo in Brazil, which was monitored for a short period (11 days)]. This building has been used as reference, for the sensitivity studies carried out for two climates, S. Paulo in Brazil and Lisbon in Portugal. The objective is to identify for the two climates, the parameters that most affect energy consumption, such as: occupation, building shell, glazing types, area and orientation. This analysis was carried out using the Environmental System Performance (ESP-r) program [Clark, 1996]. The main results for each situation are compared in order to analyse the impact of climate conditions in building design and get important recommendations for future buildings.

1 Introduction

S. Paulo is the largest city in Brazil with almost 17 million people, where the building sector produces millions of square meters per year. Lisbon is the main city in Portugal with over two million people and with a high rate of construction. In Brazil the building sector uses nearly 42% of the total energy consumption while in Portugal this is only 20%.

The building's energy consumption is directly linked to main decisions related to the envelope in the design process. These parameters are defined in the early phases of the project, which means that from then on, the items directly related to thermal and energy performance must be regarded with the same importance as structural or architectural aspects. This strategy demands a close link between the architect and the thermal engineer. It is extremely important that designers know the main parameters that will influence and determine the building energy consumption. The parameters studied in this case, glazing types (single and double), glazing areas and orientation for both countries can significantly determine the building's thermal performance and this is particularly relevant for office buildings, which are currently designed with large window areas in all countries and continents.

Nevertheless, the effect of internal gains in the building can override the parameters related to the building envelope. This is one of the items analysed in this paper, by the overall heat balance and energy consumption.

2 Experimental data

The short term monitoring was carried out in S. Paulo for a very particular building (BIRMANN 21), built very recently and designed by SOM (Skidmore Owings & Merril). One representative floor was chosen (see Fig.1), and a set of points selected to measure air temperature, over a period of about 11 days (between 28 November – 8 December 1998). Other environmental variables were recorded, such as the outdoor air temperature (point P7).

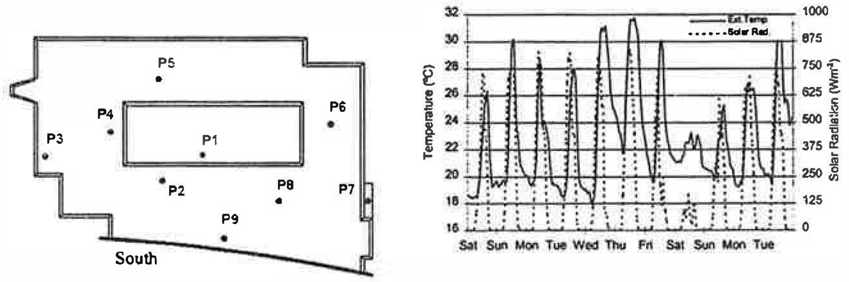


Fig.1 Floor plan including points of thermal measurements and meteorological data

The spatial zoning follows conventional office buildings, which can cause many environmental problems related to lack of privacy, acoustic disturbance and undesirable temperature fluctuations. The floor plan is extremely deep with the circulation core in the centre. Fig.2 shows the air temperatures measured for the several zones. In the south zone the measurements were taken for two positions, P9 near the glazing and P8 near the core. Temperature differences that can reach 3K.

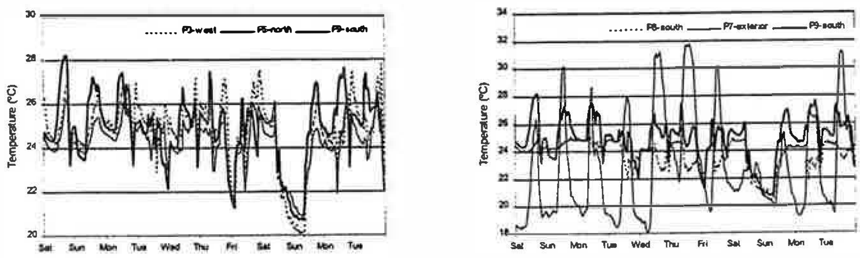


Fig.2 Indoor observed temperatures –S. Paulo

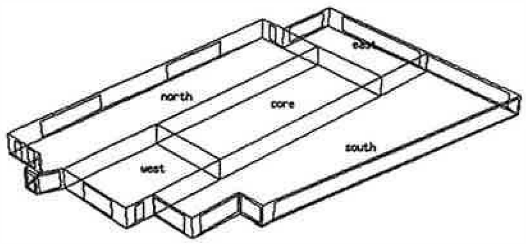
During this period the outdoor temperature varied between 18°C (minimum at night) and 32°C (maximum of the day) for a maximum global radiation between 400 and 950 W/m^2. The internal temperatures measured during the period reflect the overall running conditions of the building. During the weekends the HVAC system is off, and during the weekdays it is on. It is precisely during the weekends periods, when the building is running in a free floating condition that the internal temperatures are close to the external ones, that important differences occur between zones of the floor. These temperatures can show differences of about 2K in the maximum values between north space (P5) and south space (P9), during the first weekend. During weekdays the internal temperatures are mainly driven by the air-conditioning system. According to the results, the control is quite unstable and doesn't profit from the climate (no free-cooling). This is quite evident during the night period, when the internal gains are reduced (people, lights and equipment) and the HVAC system is off. In this case, a decrease in the temperature was expected, closer to outdoor temperatures, which in fact did not happen.

During the day, the control differs from day to day and also from zone to zone, according to the dynamic occupation schedule. As consequence of this conjunction of factors, it is quite difficult, not only to identify the parameters which most affect the experimental values, but also to compare them with the predictions obtained by simulation.

3 Building thermal model calibration

The floor of Birmann21, where the experiments were carried out, was modelled in order to perform the sensitivity analyses. The space was divided into four perimeter zones (north, south, east and west) and a core zone. Fig.3 shows a perspective view of these zones and summarises a description of the main characteristics of the envelope. The methodology followed for the study consisted of the following main steps.

- Creating the thermal model of the building (space) and its occupation
- Performing calibration: comparing simulations with measured data obtained during monitoring campaign,
- Sensitivity studies with the base model in order to quantify the influence of the building parameters identified in this study.



Glazing areas; south: 136 m^2 east: 42 m^2 west: 12 m^2 north: 60 m^2
U-values: walls: 1.6 w/ m^{2}K, glazing; Antisun bronze: 5.33 W/m^{2}K

Fig.3 Typical floor model and building envelope thermal proprieties

The input data required for the construction of the model, with ESP-r were obtained during the field campaign and from the analysis of design documentation. This information is basically of three types; geometry, construction and operation. The first item is quite easy to establish, the second: to characterise the elements, is a little more difficult and finally the last item is much more complicated and difficult to model.

The construction of the model followed the geometry of the floor and its partitions, the construction elements were obtained from the designer and builders. The first difficulty is to get the thermophysical properties of the materials, which in most part of the cases were estimated using standard tabulated data. The input parameters related with building operation, occupancy, lighting, equipment (internal gains: IG), were obtained during the monitoring campaign and used in the model, the first set of values used in the calibration process was IG1 (see Table 1). As we will see, this is the main source of problems, when trying to get close to the measurements. The uncertainties in these inputs are responsible for the great difference in the comparison of results. Regarding the climate data, the temperature was recorded in situ (P7) and the global irradiation was obtained from another place in town.

During the simulation process, the comparison between the measured temperatures and those obtained from the simulations never reached a "reasonable" degree of confidence (Figs.4 and 5). In fact, the several attempts to come closer to measured values, faced three majors obstacles; internal gains information (values and schedules), infiltration rates and cooling control.

Table 1 Internal gains (W)

	People					Equipment					Lighting	
	Weekdays				Saturday	Weekday				Saturday	Weekday	Saturday
	8-12	12-14	14-18	18-24	11-18	8-12	12-14	14-18	18-24	11-18	7-24	11-18
IG1	3175	1500	4525	750	750	12432	8880	19092	4440	2220	10786	5393
IG2	1588	750	2263	0	375	6216	4440	9546	2220	1110	5393	2696
IG3	1588	750	2263	0	0	6216	4440	9546	2220	0	5393	0

Table 1 presents the different internal gain schedules used in the calibration process. Fig.4 shows for two zones (north and south), the air temperatures obtained: differences up to 3K are observed.

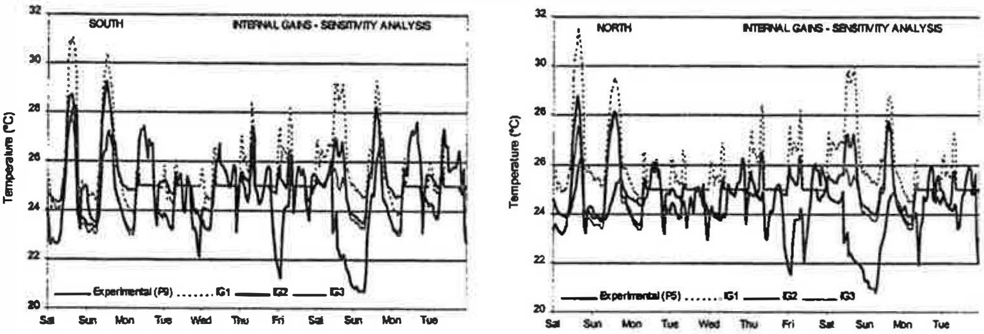


Fig.4 Internal gains effect on indoor ais temperature-south and north zone-S.Paulo

In terms of infiltration rate, three cases were simulated (Table 2). Fig.5, shows the air temperature, for these different strategies and the influence of this parameter is noticeable, mainly at night with differences up to 2K

Table 2 Infiltration rates (ACH)

Inf1		Inf2			Inf3		
Weekday	Weekend	Weekday		Weekend	Weekday		Weekend
0am-12pm	0am-12pm	0-8am	8am-12pm	0am-12pm	0-8am	8am-12pm	0am-12pm
1	1	0.5	1	0.5	0	1	0

For all the cases studied in this calibration process, the energy requirements were obtained using a set point of 25°C for cooling during the weekday, from 8 am to 12 pm. The results are presented in Table 3 in terms of kWh/m^{2}day, because the only available value to compare, is the mean value obtained in the building consumption, i.e. 0.17 kWh/m^{2}day.

Table 3 Energy consumption for internal gain and infiltration effects

Internal gain (Inf1)	kWh m^{-2} day^{-1}	Infiltration (IG2)	kWh m^{-2} day^{-1}
IG1	0.404	[illegible]	0.214
IG2	0.214	[illegible]	0.221
IG3	0.210	[illegible]	0.233

The values obtained show the importance of the operation parameters in the overall behaviour of the building and in terms of energy consumption, nevertheless all the cases IG2 with Inf1, 2 and 3 are similar.

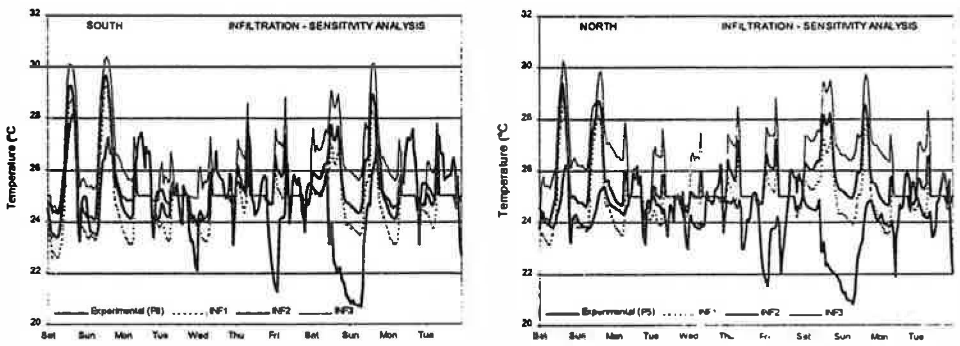


Fig.5 Infiltration rate effect on indoor ais temperature-south and north zone-S.Paulo

4 Sensitivity studies

The purpose of these studies was to provide main indications, regarding the variability of the internal thermal conditions (temperatures, heating and cooling loads), to a number of design parameters and operational variables throughout the all year, for the two climates. The following items were studied in this work; climate, internal gains, glazing types, glazing area and orientation. The simulations were done for the whole year, using weather data files (TRY). The five zones model was used, with internal gains (IG2) and infiltration rate (Inf1) and a set temperature of 25ºC for cooling and 18ºC for heating, during weekdays (8 am to 12 pm) throughout the year. Two simulations were done, for the building in free-floating mode, with and without internal gains. The main objective is to verify the influence of the internal gains on the thermal behaviour of the building. Fig.6 shows the plots for the climates. For the whole year the mean temperature increase due to internal gains is about 3-4K (depending the zones) for both climates.

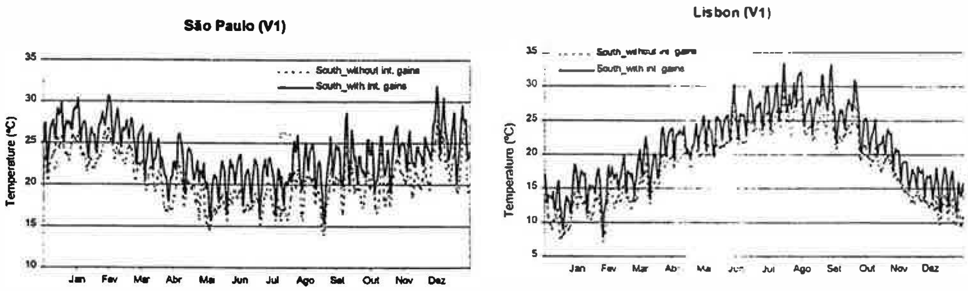


Fig.6 Annual air indoor temperatures, with and without internal gains for S.Paulo and Lisbon

An analysis was done regarding the energy consumption of the building, with and without internal gains for the whole year, Table 4 presents these results. In order to get the relative weight of the internal gains in the energy balance, an analysis was done. The results shows that for the whole year, the internal gains correspond to 49% to 55% in S. Paulo (depending on the zones) and 54% to 68% in Lisbon, greater than the solar gains.

Table 4 Annual heating and cooling energy (kWh)

	S. Paulo		[illegible]	
Internal Gains	Heating	Cooling	Heating	Cooling
without	965	13759	30720	11799
IG2	118	98570	4483	55447

Different types of glazing were studied using the same model, with the same parameters:

Table 5 Glazing properties

G1 Antisun bronze 33/48(visible transmission/total transmittance), 10mm, no blind; 1 layer; U=5.33 W/m^2K
G2 Antisun bronze 33/48, 10mm, no blind; composed of 3 layers ; U=2.80
G3 Spectrafloat 45/54, 10mm, no blind, composed of 3 layers U=2.78
G4 Clear float 73/66, 10mm, no blind; composed of 3 layers U=2.80

The results for Lisbon show energy requirements from 50 to 55MWh (cooling) and the best glazing to be G2 (Antisun Bronze-double), and 3.3 to 4.4MWh (heating) and G4 for the winter season. For S. Paulo for the heating season all types of glazing result in around 120kWh and no significant differences between them. For the cooling season 100 to 110kWh, with the best glazing solutions being G1 and G2.

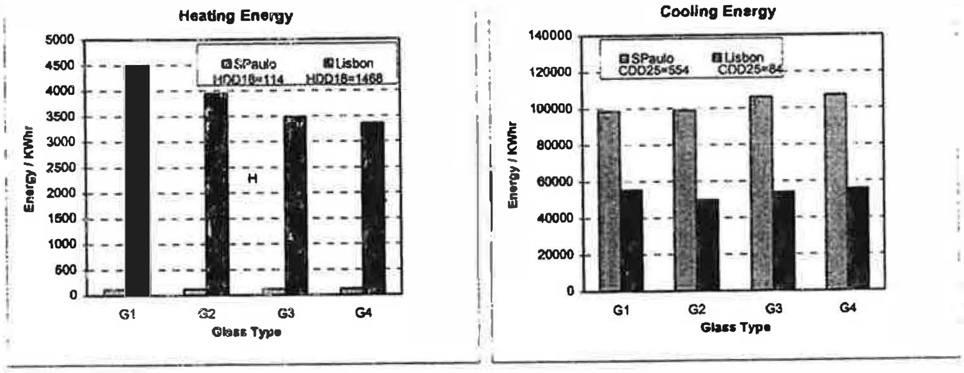


Fig.6 Energy requirements for different types of glazing for S.Paulo and Lisbon

The building was rotated 180º, which corresponds to the glazed façade of S. Paulo building facing north, and a reduction of a glazing area in south. For Lisbon the inverse, the results show for this climate a reduction of energy consumption of heating (19%) and an increase in cooling (7%). For S. Paulo the cooling requirements increase (1%).

Table 5 Effect of orientation and glazing area (kWh)

Main glass area facing	S. Paulo		Main glass area facing	Lisbon	
	Heating	Cooling		Heating	Cooling
South	118	98570	[illegible]	4484	55447
North (rotation 180°)	118	99684	[illegible]	3636	59109

5 Conclusions

- The internal gains are the main factor on energy consumption in this type of building. For both climates these values are responsible for an increase in air temperature of 3-4K, for S. Paulo, the cooling energy need is 7 times higher with than without internal gains, for Lisbon 5 times.
- For both climates the energy requirements are mainly for cooling. In S. Paulo no heating is necessary.
- The best glazing for both towns is the *antisun* glazing, with slight differences in S. Paulo between the single and the double. In Lisbon the double has some advantage, also in the heating season.

6 References

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