Monitoring of a Double Skin Façade Building: Methodology and Office Thermal and Energy Performance

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Summary: *This paper concerns to the post-occupancy monitoring of a building sited in Lisbon with transparent double-skin façades. This is the first of an enlarged monitoring program covering other buildings and weather conditions, aiming to clarify under which climate and performing conditions this architectural solution is acceptable. Within this campaign an enlarged set of parameters was measured from external conditions to energy consumption and indoor comfort. The present paper describes the building, presents the monitoring methodology and analyses the thermal and energy performance of a specific office space.*

Keywords: *double-skin façade, monitoring, energy performance*
Category: *Building design, construction, operation and management*

1 Introduction

A subject currently being discussed among the research community of building physics is that of the performance of double skin façades (DSF). This architectural / engineering solution gained acceptance as an element of *advanced integrated façades*, and, despite being more common in central and northern European countries, several buildings using this technology have been constructed also in southern European countries, such as Portugal.

The sunspace effect of DSF technology is associated with reduced energy needs for heating, during cold weather, and is therefore considered an energy efficient technology. During warmer periods DSF can cause overheating problems and/or increased energy needs for cooling, specially if the appropriate shading and ventilation of the DSF is not considered.

In Lisbon, different typologies of DSF buildings have been built in recent years. Despite the studies made during the design stages, until now no monitoring has been performed to assess real DSF technology subject to Lisbon's weather conditions.

This paper describes such a monitoring work and presents results that characterize the behavior of an office in a DSF building located in Lisbon, during mid season conditions.

The monitoring covered energy consumption, visual, acoustic and thermal comfort, and concentrated also on the heat transfer analysis in the cavity between both façades. Due to the amount of data gathered, results specific for the thermal behavior of the cavity between both façades is presented in an independent paper [1]. Monitoring results on acoustic, visual and thermal comfort indoors are also presented independently in [2]. This paper presents the overall building description, monitoring methodology and presents results on the thermal and energy performance of an office in the studied DSF building.

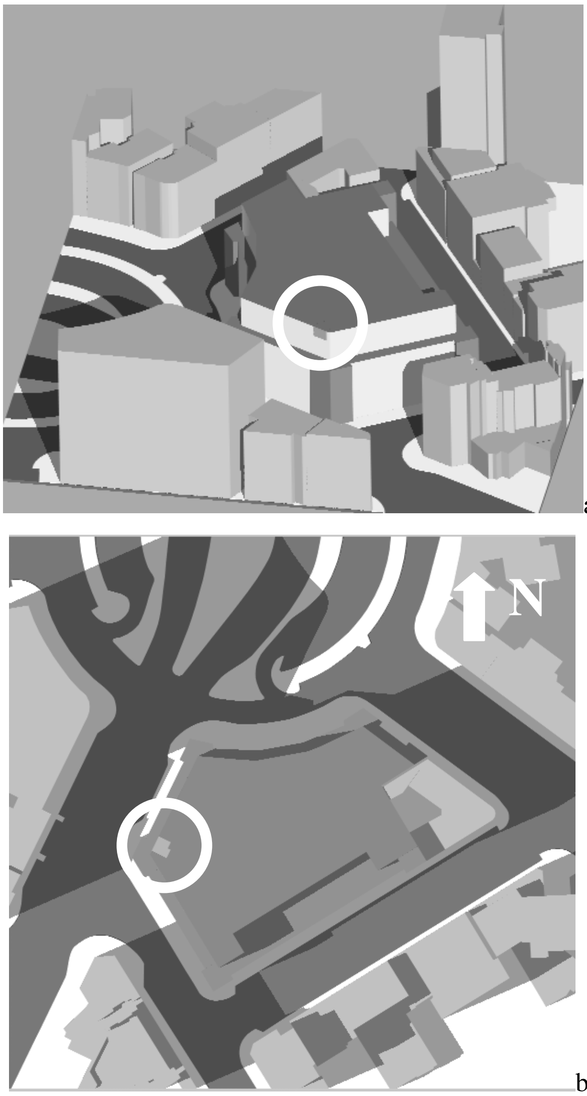
2 The double skin façade building

Atrium Saldanha is an eleven storey building located in a busy commercial and office area in Lisbon. The building occupies a whole block — see Figure 1. Possessing a modular structure and a light construction type (façades with almost 100% glazing areas), the building develops itself around an atrium — for commercial use — where office spaces lie. In 1998, when the building started to be used, it was one of the first Portuguese buildings to use DSF technology. Having a total above ground construction area of 40000 m^2, 29000 m^2 used as office spaces and 11000 m^2 for shopping, the architects considered the adoption of DSF to increase energy efficiency, reduce traffic noise, and create a feeling of connection among office workers and shopping visitors.

Double-skin façades are used on all orientations (SE; SW; NW; NE); the SW and half of the North DSF possess mechanical ventilation in the air gap (working days from 8:00 to 18:00).

The air gap has a depth of 0,83 m and both the inside and outside skin are glazed — 10 mm thick single pane transparent glazing (g=0.77) and 12 mm thick single pane transparent glazing (g=0,75) for the inside and outside skins, respectively. The DSF is partitioned horizontally every two or three stories. Manually operated black fabric rollers located inside the air gap (near to the inner skin) are used for shading.

As Figure 1 shows, Atrium Saldanha is located near a square. Due to heavy traffic, noise and air pollution are subjects of concern.



a)

b)

Figure 1. 3D views of Atrium Saldanha. Inside the white circles is the office space that will be monitored.

Facing SW, in the 11th floor (last floor), is located the office space that was used in the monitoring campaign. Its location and orientation is suitable to identify overheating conditions, since high outside air temperatures and solar gains are achieved during the afternoons in the SW orientation. The location of the monitored office is identified in Figure 1 (inside the circle).

From its conception Atrium Saldanha considered features to reduce energy costs, such as a centralized managing and control system, and ice storage tanks. The high building transparency and the fact that the double skin is horizontally partitioned every three stories (height of 9,8 m in the studied SW region) contributes to higher air temperatures in the cavity, which can lead to overheating and possible damage of glazing elements [3]. Figure 2 shows values of air temperature measured inside the air gap.

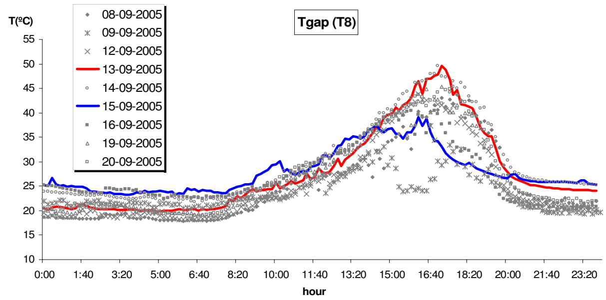


Figure 2. Air temperature results inside the air gap of the DSF adjacent to the monitored office space (from 8th to 20th September 2005).

Figure 2 shows that the mechanical ventilation of the air gap does not prevent the occurrence of air temperatures close to 50ºC.

3 Monitoring methodology

The reasons leading to the monitoring of DSF buildings under Southern Europe climate conditions are mainly the need to i) understanding their behaviour, and; ii) obtain data under post-occupancy buildings, in order to properly evaluate how they work from comfort and energy use points of view and to improve and validate models and predictions from design tools.

A set of monitoring campaigns on some DSF Lisbon buildings, for summer, winter and midseason conditions, was programmed where a set of parameters will be measured to assess the thermal behaviour of the façades, outdoor and indoor conditions, lighting, acoustics, thermal comfort and energy consumption.

This paper focus on the first campaign, between September 8th and 20th, on a multi-storey, external air curtain, mechanically ventilated DSF.

Other buildings to be monitored have different types of façade and next campaigns are scheduled for December/January/February and July/August.

Other important factor of choice is the occupancy (besides the obvious need of availability).

4 Office thermal and energy performance

Energy sources used in the office space are electricity and cold water (also hot water during winter).

Heated and cooled air is introduced in the office from an elevated floor and extracted at ceiling level (similar to a displacement scheme). Each office/tenant has its individual electricity, heating and cooling water meters. The thermal cooling energy in the office was determined from the cold water flow meter.

Electricity is used for lighting, computers / printers / faxes and local air inflow. Due to the inner and outer skin transparency no ceiling lighting is considered near the façade, only task lighting. Due to glare related problems or to excess solar radiation the use of the roller blinds can justify the use of artificial task lighting even during the day.

Figure 3 compares registered values of total power consumption (P) to office indoor air temperature (T).

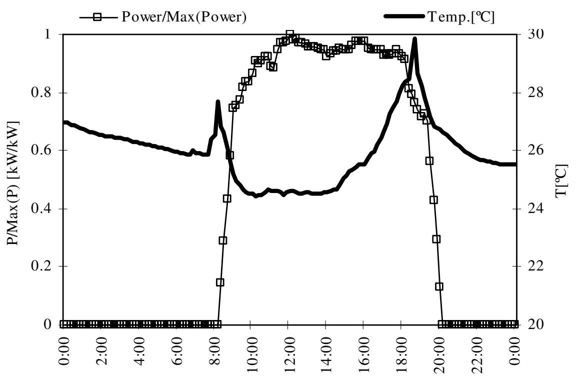


Figure 3. Power consumption (adimensionalised to the maximum daily value) versus office indoor air temperature.

It can be concluded that the cooling system is decisive for the maintenance of indoor temperatures at about 24ºC. A sharp rise in indoor air temperature occurs, however, after 16h00, suggesting that cooling system in unable to contradict the increase in office temperature, and some overheating can occur in the monitored office. The specific location of the monitored office does not allow extrapolations of this conclusion to other offices with other (in general more favorable) orientations.

Figure 4 shows values of incident solar radiation (Rad.), measured behind the inner glass pane, and compares theses values with measurements of heat flux (q'') entering the office.

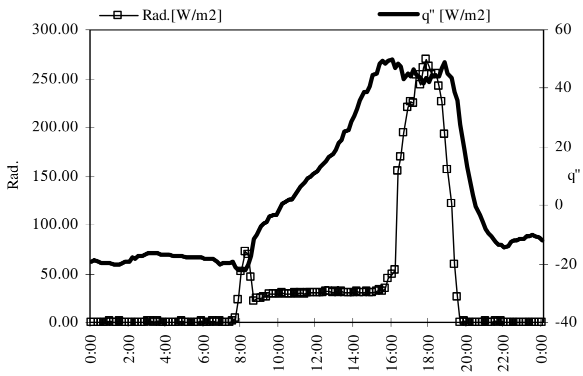


Figure 4. Incident solar radiation versus heat flux entering the office (positive heat flux means heat entering the office space).

It can be concluded that a peak of incoming radiation occurs at 18h00. Figure 5 presents schematically (in plant and elevation views of the office) the degree of solar radiation that enters the monitored office at different hours of the day.

The high level of solar radiation that enters the office space is at least partly responsible for the increase of the indoor air temperature after 16h00 — see Figure 3. However, according to Figure 4 solar radiation doesn't seem to be the only factor determining cavity air temperature; since heat flux transferred by convection through the inner façade appears to be independent of the peak radiation.

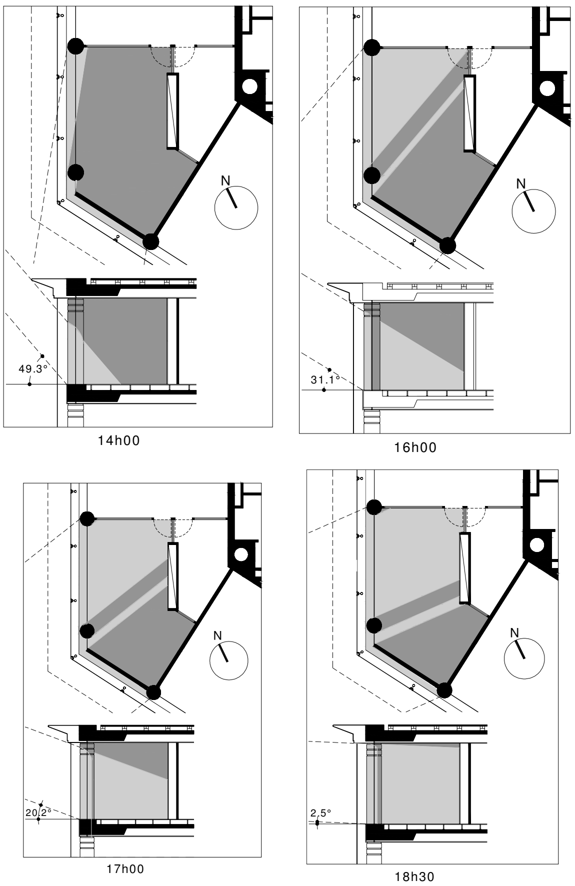


Figure 5. Incoming solar radiation at different hours.

5 Conclusion

With the monitoring work performed it was possible to assess the thermal and energy consumption performance in a DSF office, considering Portuguese weather conditions. For this office it was concluded that the cooling system was fundamental to the maintenance of indoor air temperature and that overheating can actually occur when high air cavity temperature and high solar radiation coincide.

It is interesting to state, however, that from the results of a preliminary assessment on occupant satisfaction it was not possible to conclude that people felt uncomfortable in the monitored office space. When the occupants that worked close to the DSF (less than 2 m) were asked about their will to change working place to one further away from the façade, the answers revealed that glare and thermal discomfort were not enough to justify any changes. It would be interesting to investigate if holistic comfort models are more fit for modeling users comfort inside the monitored DSF building, that, despite being mechanically cooled, has also — due to the DSF — a high transparency. Further monitoring during winter and summer periods should allow also a better understanding of the office energy consumption, thermal behavior and occupant satisfaction.

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