Façades Design and Environmental Performance in Buildings in Chiado

Natasha Redin and Manuel Correia Guedes

Instituto Superior Técnico, Universidade Técnica de Lisboa, Lisboa, Portugal

ABSTRACT: The present work aims to analyze the environmental performance of Chiado buildings façades and contribute to the development of passive design strategies in buildings in this area. Chiado is located in downtown Lisbon, in the heart of its historic centre, and integrates the World Heritage candidate area of Baixa Pombalina. The analysis of the climatic context and its influence in Chiado urban space and façade design is presented. The field work was carried out in four case studies, involving physical measurements, inquiries to the occupants and simulations, aiming at developing passive design strategies.

Keywords: Façades Design, Energy Rehabilitation, Daylight, Environmental Performance, Baixa Pombalina, Chiado

1. INTRODUCTION

Façades are the building's "skin"'. Their design is critical in terms of the provision of comfort to the occupants and in terms of energy consumption. The façade must be a finely tuned "instrument of dialog" with the local climate, adapted to it, in order to reduce the negative impact of energy consumption to the environment, and promote occupant satisfaction.

One of the most efficient sustainability strategies is the refurbishment of existing buildings because this potentially involves a lower environmental impact, for instance through the reduction of embodied energy associated with demolition and a new construction.

Chiado is an historical area in the heart of Lisbon and it's located in a zone where most of the buildings date from the rebuilding Plan after the large 1755 earthquake. The urban planning of this area had among its main objectives the improvement of the ventilation and natural illumination conditions, i.e. in relation to the old city dense and unruly design.

Later in 1988 this zone became an example of large-scale rehabilitation after a considerable fire destroyed partially or completely 17 buildings. The Plan elaborated after the fire, by the architect Álvaro Siza Vieira, involved efforts on the part of the Municipality, the proprietors and users in order to restore an important part of the city, its history, culture and society.

The present paper is divided in three parts. In the first part it is intended to analyze the façades design and the environmental performance in relation to the local climate. In the second part to deepen the previous comments through the analysis of results from the field study, which involved physical measurements, inquiries to the occupants and software simulation. The third part presents recommendations of passive design strategies in façade design rehabilitation.

2. FAÇADES' DESIGN

The different types of façade design that we can find nowadays in Chiado are mostly from the 1758 rebuilding Plan, with a wood and masonry structure. The majority of the buildings that have been rehabilitated possess a reinforced concrete structure, but kept the original masonry outer wall. In some cases where the façade was rebuilt, the former design was maintained based in the existing elevation drawings kept by the Municipality Archive.

The two main types of façade that we can find in the area of the Chiado are mainly:

1. The façade with wood and masonry structure, built approximately in 1758;
2. The façade with reinforced concrete and masonry, built approximately in the 90s and beginning of XXI century;

2.1. Façade with wood and masonry structure

These types of façades were built after the 1755 earthquake and they were constructed with irregular rock stones and fragments of rocks and ceramics, bound with mortar. The exterior walls possess a thickness of 90 cm in the first floor from which it initiates the wooden structure. These buildings have five storeys; the first floor is higher and has wider openings in order to support the stores. In the second floor the openings have a small balcony and in the remaining floors the openings are smaller (Fig.1).

2.2. Façade with reinforced concrete and masonry

The rehabilitation of these façades was made replacing the wooden structure by one with reinforced concrete, where the original masonry façades were kept in the exterior by means of anchors to the structure of the building. The façades that were destroyed by the fire were rebuilt with contemporary materials and techniques but looked forward to maintaining the original characteristics of the original buildings. However in this case the great thickness of the exterior walls was reduced.

Another type of façade design found in this area are contemporary (Fig.1) and are located inside inner patios were the depth of some buildings was reduced. These façades did not exist previously, so they were elaborated by Siza Vieira following the drawing composition of the old buildings as in for example the dimensions of the openings, the vertical hierarchy of storeys and alignments.

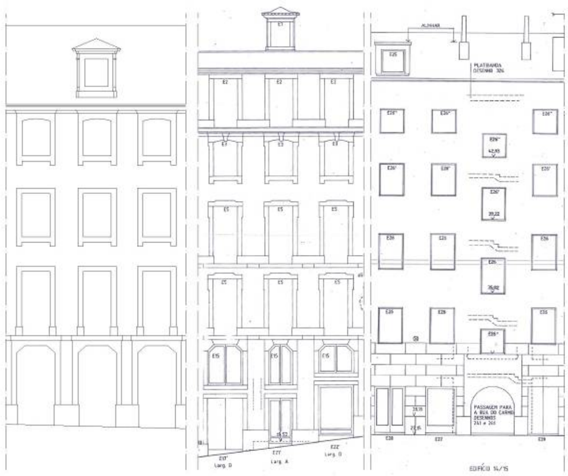

Figure 1: Types of façade design in Chiado [1].

3. CLIMATE DESCRIPTION

The climate of Lisbon (latitude 38º 43'N) is mild, however in the summer it is rather hot. The average temperature range from the winter to the summer can reach up to 10ºC. The maximum temperatures reach approximately 38º and 41ºC in the summer and about 0.5ºC in the winter (Fig.2). Lisbon is one of the cities of Europe with highest availability of solar radiation with 2800 hours per year, reaching the maximum values in the months of July and August.

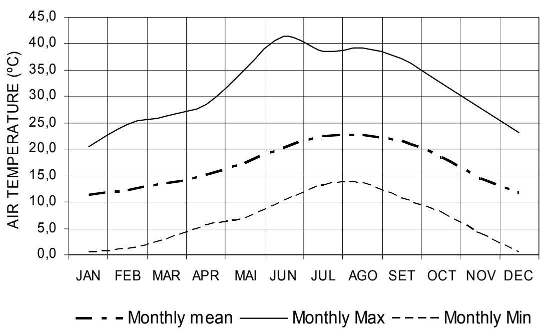

Figure 2: Air temperature in Lisbon [2].

4. FIELD STUDY ANALYSIS

The field work was carried through the hottest period of the year, in August 2005, in four office buildings in the Chiado area. These buildings were chosen as representative for the study based in design of the façade, type of construction, orientation and availability and willingness of the office administration.

The main objectives of this study were to assess the thermal and light performance of the façades design and to give more scientific depth to the previous comments.

The buildings in study were shaped in three dimensions for simulation with the software *Ecotect* [3]. The models simulations for the case study were elaborated from existing drawings and local made drawings with a climatic data reference similar to the registered data.

The quantitative evaluation was made through temperature and light measurements. The measurements of the thermal conditions were recorded during the period of five days (corresponding to one week of common work) and the measurements of the light conditions were recorded in one day with three daily measurements (corresponding to one typical work day). The qualitative evaluation was made through inquiries to the occupants. The main objective of the inquiries was to evaluate the level of satisfaction of the occupants and the comfort sensations in the different buildings, and finally to compare this information with the results from the thermal and light environment.

Figure 3: Castro and Melo Building

4.1. Castro and Melo Building

The building Castro and Melo (Fig.3) is located in one of the main streets in the Chiado area. The façade is made of reinforced concrete and masonry, while the original façade was kept in the exterior. The parcel measured has 76m^2 area and 3.10m in height. The cooling system functions in Mix-mode adjusted by the workers. The glazing area is approximately 30% facing east. The temperature measurements (Fig.4) were relatively constant with a small thermal amplitude in the interior (26º-29ºC) relative to the exterior (19º-38ºC) revealing a good performance of the outer walls. The model simulations showed that the temperatures in the inner compartments are higher than in the cabinets adjacent to the façade, due to lack of ventilation openings in the inner spaces of the building. In the results of the inquiries all the occupants had considered the temperature satisfactory and all had preferred a little more cold. In the calculation of PMV and PPD, the values are above the results of the inquiries, which raises the possibility that the adaptive actions [5] of the occupants (not measured in the calculation) may have influenced the results. The values of light measurements were adequate for the performance of the visual tasks. However, in the inner compartments in late afternoon the values were insufficient. In the results of inquiries, 75% of the occupants had considered the natural light satisfactory and the amount of light more than enough. 75% of the occupants considered the artificial light satisfactory and 50% considered the amount of light enough. The relation of the height with the depth of the individual cabinets is well adjusted. 60% of the total area of the parcel is passive area. The active zone is used for circulation areas, secondary compartments and for other activities which are not adjusted to the localization in the parcel. The internal shading devices are roller blinds in translucent fabric that provide a good distribution of the light and prevent the visual discomfort provoked by glare from the windows.

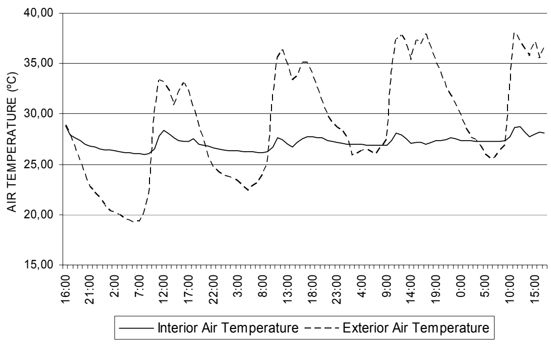

Figure 4: Temperature measurements in Castro and Melo building.

4.2. Anchieta Building

This building is located in a secondary street in the Chiado area. The façade is typical from the 1758 Plan (Fig.5) in wood and masonry structure with some interior renovations in the 70s. The parcel measured has 150m^2 area with 3.30m in height. It doesn't possess any mechanical cooling system. The glazing area is approximately 16% facing West – which is rather below the recommended values in the LT Method [4] for Lisbon climate – however it originates, mainly during the afternoon, a lot of direct sunlight in the interior spaces of the building. In this parcel the opposing openings in the building make possible the creation of diurnal and nocturnal ventilation for scanning the heat from the internal compartments. The temperature measurements (Fig.6) remained relatively constant with a small thermal amplitude in the interior (26º-28ºC) relative to the one of the exterior (21º-30ºC), revealing a high thermal mass in the façade. In the results of the inquiries all the occupants considered the temperature satisfactory and 40% preferred a little more cold. In the light measurements the results were extreme along the day in the compartment with bright surfaces, while in the remaining areas with dark surfaces the results were insufficient for the performance of the common visual tasks. In the compartments the shading devices used – double curtain blinds – and the room reflectance were the main causes for the bad results in the light measurements leading to the conclusion that they are not adjust to the visual tasks for the activities in this parcel. However in the results of the inquiries all the occupants considered the natural and artificial light satisfactory and 60% considered the amount more than enough. This probably is due to the use of artificial light during all day – as it was observed during the study – and the adaptive actions taken by the occupants that were not measured in this study. The relation of the height with the depth of the individual cabinets is well adjusted. 75% of the total area of the parcel is passive. The active zone is used for circulation and closets.

Figure 5: Anchieta Building

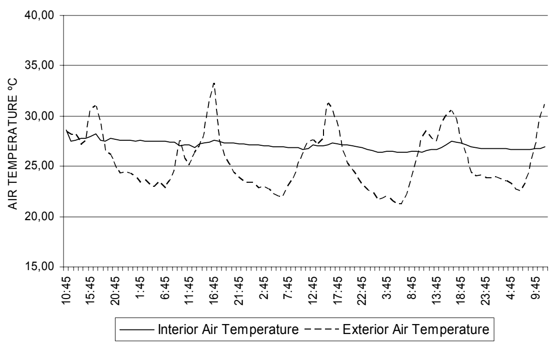

Figure 6: Temperature measurements in Anchieta building.

4.3. Oliveira do Carmo Building

This building is located in a main plaza in the Chiado area. The façade is made in reinforcing concrete and masonry, where the original façade was kept in the exterior. All the interior of this building was reconstructed and the interior compartments substituted by open space floors. The parcel measured has 105 m^2 area with 2.70 m in height. The small ceiling height is due to the suspended ceiling and an elevated floor for the installation of the air-conditioning, artificial light and technical wiring. The air-conditioning system functions with automatic control between 7am and 7pm, around a temperature between 23º-24ºC. The glazing area is 30% facing East and South. The temperature measurements remained relatively constant with the functioning of the air-conditioning system (22º-27ºC) in relation to the exterior (18º-30ºC). During the night – when the air-conditioning is off – the exterior walls freed the heat absorbed during the day – increasing the temperatures inside the parcel – revealing a high thermal mass of the façades. In the results of inquiries (Fig.7) 50% of the occupants considered the temperature satisfactory, 44% not satisfactory and 6% very unsatisfactory. The dissatisfaction of the occupants with the temperature are due to the lack of efficiency from the air-conditioning system and the absence of the system control by the workers – as some complaints were recorded during the study.

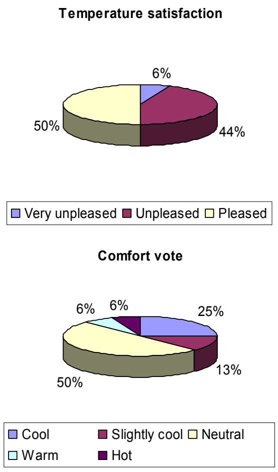

Figure 7: Inquiries to the workers in Oliveira do Carmo building.

In the simulation results of the building model, the PMV calculated was 1.3 and the PPD was 40%. These values reveal the potentiality that this building has for functioning without the mechanical cooling system and the possibility of implementation of passive design strategies with a wider possibility of adaptive actions by the workers. In the measurements of light the values have shown extreme levels of light for the performance of the visual tasks, due to the inefficient installation of artificial lights. The model simulation revealed the potentiality of the building for the implementation of passive daylight design fulfilling the illumination requirements. In the results of inquiries, 56% of the occupants considered the natural light not satisfactory and 50% did not consider the amount sufficient. 63% of the occupants considered the artificial light satisfactory and 31% unsatisfactory, and 70% considered the amount extreme. The relation of the height with the depth of the space is not adjusted. 50% of the total area of the parcel is passive area, used for closets and circulation. The active area is used for circulation and performance of activities not adjusted to the localization in the parcel. The internal shading devices – roller and venetian blinds –, the dark surfaces and the small ceiling height, do not provide a good distribution of light trough the space.

4.4. Carmo Building

This building is located in one of the main streets in the Chiado area. The façade is made of reinforced concrete and masonry, and the original façade was kept in the exterior. All the interior of this building was reconstructed and the interior compartments substituted by open space floors. At the same time the depth of the building was reduced to create an interior patio inside the block, which leads to a new façade for the building (Fig.8). The parcel measured has 90 m^2 area with 3.20 m in height. The air-conditioning functions in Mix-mode regulated by the workers. The glazing area is 30% facing East and West. The temperature measurements remained relatively constant with a small thermal amplitude in the interior (24º-28ºC) relative to the exterior (22º-29ºC), revealing a good performance of the exterior walls. In the results of inquiries, 80% of the occupants considered the temperature satisfactory and 40% preferred a little more cold. In the light measurements the values have shown extreme levels of light for the performance of the visual tasks, due to the inefficiency installation of artificial lights. In the simulation results of the building model, the values had revealed the potentiality of the building for the implementation of passive daylight design fulfilling the illumination requirements. In the results of inquiries, 80% of the occupants considered the natural light satisfactory and more than enough in amount. 60% of the occupants considered the artificial light satisfactory and considered the amount extreme. The relation of the height with the depth of the individual cabinets is well adjusted and provides a good distribution of natural light inside the space. 85% of the total area of the parcel is passive area. The active zone is used for areas of circulation and secondary compartments.

Figure 8: Carmo Building.

5. DESIGN RECOMMENDATIONS

Aiming at developing passive design strategies in the rehabilitation of façades in the Chiado area and the creation of satisfactory levels of thermal and visual comfort the following aspects must be considered:

1. Most of buildings in this area, essentially the older buildings, possess exterior walls with a great thickness that provides a high thermal mass. In the rehabilitation the high thermal mass was maintained as the original façade. In addition, reinforced concrete elements were added as well as thermal insulation panels between the

masonry and the concrete. In rebuilt façades, reinforcement was made trough the application of thermal insulation panels between the double masonry walls. This solution is currently most used in the construction of new buildings, although it can be considered of high thermal mass, the absorption of heat is lesser than the exterior walls of the older buildings.

2. The main means of solar captation in buildings in this area is through the existing openings in the façades and through skylights placed in the buildings roof (Fig.9). The main disadvantages in this system are the dependence in solar radiation availability and the possibility of overheating the inner spaces. However, skylights that cover small patios or stairs to access the building, simultaneously allow the entrance of daylight to the interior of the building and profit from solar energy gains trough the adjacent spaces.

3. The openings in most of the older buildings possess double casement windows with a superior awning that makes possible a higher flow of air at the level of the occupants and the movement of air next to the ceiling, were the heat is concentrated. However, in the summer when the temperatures are high, the openings can originate heat gains through ventilation.

4. The day lighting elements to use in control glare and block sunlight that we find in most of the buildings are internal shutters, which had been introduced or reintroduced in the buildings rehabilitated after the 1988 fire. These elements provide in the summer the total blockage of the entrance of the solar radiation and also strengthen the thermal insulation of the envelope in buildings, reducing the thermal losses trough the openings, however they produced a diminishing in the levels of light in the interior for the good performance of the visual tasks.

Figure 9: Skylights and window with an internal shutter

6. CONCLUSION

Maintaining the original exterior façade expresses the best way of rehabilitation of these buildings. In these cases the environment performance of the façades is more efficient and proves to be adequate to the local climate and simultaneously keep the historical, social and cultural characteristics of the urban space.

The modifications of the partitioning of the old buildings, types of glazing, shading devices and the introduction of artificial acclimatization and lighting systems modifies the environment performance of the building (Fig. 10) and the levels of satisfaction of the occupants, and therefore affect the energy consumption in this buildings. As it was observed in the field study this type of modifications like the installation of artificial acclimatization, common in the new office buildings, and the excessive use of artificial light can provide a diminishing in the environment performance of the building and reduce levels of satisfaction in the workers.

The deepen study and implementation of passive design strategies in projects of rehabilitation can lead to a better environment performance and therefore increase the satisfaction levels of the workers, representing important aspects to be consider in the future rehabilitation projects. This can represent a better energy efficient measure and an important sustainability strategy.

Figure 10: Oliveira do Carmo Building

ACKNOWLEDGEMENT

This present paper shows some of the results on a Msc. Research undertaken in the Instituto Superior Técnico da Universidade Técnica de Lisboa, under the supervision of Prof. Manuel Correia Guedes.

REFERENCES

[1] Vieira, Álvaro Siza, Elevation drawings, 1993
[2] Instituto Nacional de Meteorologia e Geofísica, 1991
[3] Marsh, Andrew J. Ecotect version 5.20, Square One Research, 2003
[4] Baker and Steemers, Energy and Environment in Architecture – A Technical Design Guide, E&FN Spon, London, 2000
[5] De Dear and Brager, Developing an Adaptive Model of Thermal Comfort and Preference, ASHRAE RP-884 Project, Atlanta, 1998