Public Offices Buildings in Brasília: a point of view of Environmental Comfort

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ABSTRACT: The Modernist Movement disseminated a simple formal language architecture with repeating solutions, in name of savings, faster constructions and to take advantage of the existing technique, such as using concrete and glass. Environmental control of the indoor conditions began to be made mainly by artificial means, such as air-conditioning devices, instead of using the building envelope. Considering that the façade is one of the main responsibles for thermal gains, this work seeks to characterize and analyze the solutions adopted in the façades treatment of the public office buildings located in the Gregária and Monumental scales of Brasília Pilot Plan, from the standpoint of environmental comfort. To do so, a photographic and quantitative survey of 135 public office buildings façades was made, observing orientations, opaque and transparent elements and types of external shading devices. It was verified the adoption of similar solutions, such as an excessive use of glass, the external shading device types and building shapes, regardless of the solar orientation. This work intends to contribute in understanding environmental comfort problems in public office buildings in Brasília, offering elements for improving their thermal and luminous behavior.

Keywords: Environmental Comfort; Public Offices Buildings; Brasília

1. INTRODUCTION

The Industrial Revolution provided freedom to building designs, due to the development of new materials and construction methods. The Modernist Architecture, especially the architect Le Corbusier, took great advantage of the new resources. He proposed a house for all climates, establishing an universal man, through the standardization of habitations, seen as "Machines for Living", and cities. The architect established "the five points for a new architecture": supports, roof gardens, free design of the ground plan, free design of the façade and horizontal windows, that were used as a design manual, ignoring the insertion context both in physico-environmental and socio-cultural aspects.

In some of his theories, Le Corbusier also showed a certain concern about climatic issues, mentioning questions of insolation and illumination, for instance. In order to avoid thermal gains through the curtain wall, an evolution of the horizontal window which was thought only to illuminate and not to ventilate, he conceived the shading devices during the design of a project in Algeria.

The modernist ideas were adopted in several places, such as in Brasília, Brazil. The city is a practical example of the application of the modernist standardized ideas, been characterized by a repetition of the adopted solutions: symmetry, zoning, building height, horizontal projections, similar finishing materials and little concern with the proper orientation regarding the winds and the sun.

As a result, despite the fact that Brasília presents better comfort conditions than the 14 biggest brazilian cities [1], several researches point out criticisms to the thermal and energy performances of its buildings. Regarding the public office buildings, researches show excessive illuminance in some of them, such as the Palácio Itamaraty and the Funasa building, and conclude that buildings with a large use of glass present, in general, a higher energy consumption, even in case of glasses with solar control films or laminated with solar control [2].

Considering that the façade is one of the main responsibles for thermal gains, this paper seeks to characterize and analyze the solutions adopted in the façades treatment of the public office buildings located in the Gregária and Monumental scales of Brasília Pilot Plan, from the standpoint of environmental comfort.

This work becomes relevant as we consider that Brasília is the country capital city, concentrating a significant amount of public office buildings, and thus presenting a great potential for energy savings.

2. BRASÍLIA AND THE CLIMATIC ASPECTS

The Federal District is located between parallels 15º30' and 16º3' and meridians 47º18' e 48º17' west of Greenwich, presenting a altitude tropical climate with two well-defined seasons: a humid-hot one, from October to April, and a dry one, from May to September. We can also identify a third period inside the dry season, which goes from August to September [3].

Some of the recent data, such as temperature and humidity, were compiled and recorded in 8760 hours of a test reference year (TRY), and a Bioclimatic Chart was generated using the Analysis Bio software, which is based in the Givoni's Bioclimatic Chart [4]. The chart presented a percentage of 41,2% of comfort and 58,8% of discomfort, which can be divided in 36,6% of discomfort caused by coldness and 22,2% caused by heat (Table 1). The chart suggests as bioclimatic strategies for the region, among others, thermal mass for heating (31,3%) and cooling (8,29%), ventilation (21,2%) and artificial conditioning (0,08%) during the period of discomfort from heat and solar heating (4,37%) for some cold periods.

Table 1: Bioclimatic strategies (%). Source: Adapted from Maciel, 2002.

COMFORT			41,2
DISCOMFORT	Coldness – 36,6%	Thermal mass for heating	31,3
		Passive solar heating	4,37
		Artificial heating	0,99
	Heat – 22,2%	Ventilation	21,2
		Evaporative cooling	8,38
		Thermal mass for cooling	8,29
		Air conditioning	0,08

The recorded discomfort hours go from 11:00 am e 5:00 pm in the humid-hot and in the dry-hot periods. In the other months, the discomfort from heat represents less than 6% and occurs only between 1:00 pm and 4:00 pm [5].

Regarding the decisions to be made during the project initial stages, it is suggested: compact constructions, in order to comply to the requirements of different seasons; largest façades with north/south orientation; heavy walls with thermal transmittance smaller than or equal to 2,20 W/mºK, thermal lag greater than or equal to 6,5h and Solar Factor of 3,5; average windows of 15% to 25% for ventilation; need of only 60% of shading, due to the cold months, utilizing shading devices properly oriented and sized for each situation.

It is also indicated: façades and solar protection with light colors, as they absorb a smaller amount of solar radiation, preferably moved away from the façades, in order to transmit less heat by conduction and facilitate heat exchanges between the protectors and the air. Regarding the amount of glass on the façades, the west one must have the smallest proportion (22%), and the south one, the largest proportion (42%), when we are considering buildings with a laminar shape, with proportion 2:1 and room index (K) equal to 5.

In this context, the building envelope assumes the function of controlling in an adequate manner the interferences from the exterior medium, with the façade as one of the most important responsibles for thermal gains. Corbella [6] emphasizes the need for façade protection. The author cites a research developed in Porto Alegre, Brazil, indicating that the proper use of shading devices as a protector reduces the received solar energy from 2000 kWh/day to 820 kWh/day, i.e. 59%, in a certain building. However, they are generally neither sized nor specified correctly, and, many times, only aesthetic issues are considered.

3. METHODOLOGY

3.1 Sampling

This work analyzed 135 public office buildings located in the Gregária and Monumental scales of Brasília Pilot Plan (Figure 1). The scales were established in the city urban plan and are in a number of four: "Bucólica, Residential, Gregária and Monumental". The Monumental scale corresponds to the Monumental Axis, in the east-west direction, going from Praça dos Três Poderes until the Rodoferroviária. The Gregária scale is composed of the four corners resulting from the crossing of the Monumental and Rodoviário axes, representing the city center and concentrating the services sector.

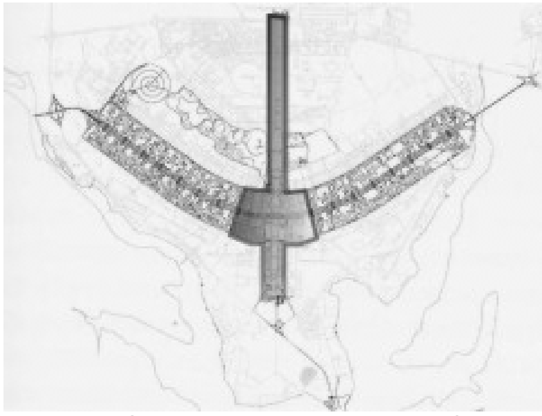

Figure 1: Gregária and Monumental Scales in Brasília Pilot Plan.

After a first survey in the studied scales, public office buildings were found in the following sectors: "Setor de Autarquias Norte e Sul (SAUN/SAUS), Setor Bancário Norte e Sul (SBN/SBS), Setor de Rádio e Televisão Sul (SRTVS), Setor de Grandes Áreas Sul (SGAS), Setor de Edifícios Públicos Sul (SEPS), Praça Municipal (PMU), Setor de Administração do DF (SADF), Setor de Administração Federal Sul (SAFS), Esplanada dos Ministérios (EMI) and Praça dos Três Poderes (PTP)" (Table 2).

Table 2: Number of studied public office buildings in the sectors located in the Gragária and Monumental scales of Brasília Pilot Plan.

SECTOR	NUMBER OF BUILDINGS	SECTOR	NUMBER OF BUILDINGS
SAUN	4	SAUS	38
SBN	10	SBS	12
PTP/EMI	41	SRTVS	1
SAFS	12	SGAS	2
PMU	14	SEPS	1

3.2 Data collection

A photographic and quantitative survey of the buildings façades was made, during November 2005, collecting data into tables. Different aspects of the constructions were observed, such as number of floors, orientation and shape, as well as the opaque and transparents elements. It was identified the types of windows and protection elements used, such as shading devices, marquees and glass color [7].

In order to complement the informations about the shading devices, another table was made, where it was clarified the amount of glazed façades and specified how many were protected as well as their orientations and the characteristics of the used shading devices. From the results of the survey, it was possible to compute indicative percentages of the adopted solutions and graphs for subsequent analysis, utilizing the Microsoft Excel software.

4. PARTIAL RESULTS AND DISCUSSION

4.1 Orientation and Solar Radiation

The building orientation is a factor of great influence in the first steps of composing a project, defining many times the architectural idea to be adopted. The major part of the studied buildings were implanted separately and in parallel or perpendicularly to the Rodoviário or the Monumental axes, not following any rule. In that way, the predominant orientations are: 108º/288º and 18º/198º, which are equivalent to 65,9% and 25,2% of the studied cases, respectively, and 8,9% corresponding to other orientations, which have single examples (Figure 2).

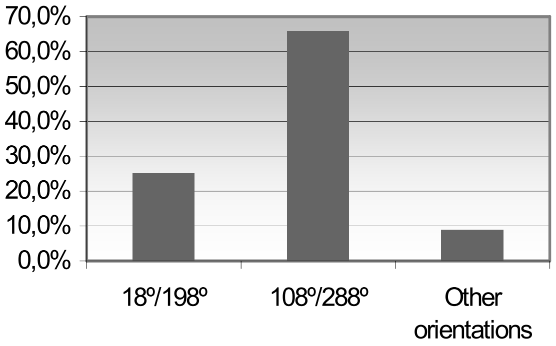

Figure 2: Predominant orientations for the studied buildings

Superposing to the solar chart [8] (Figure 3), we can verify that for buildings with orientation 108º/288º (hereafter called A-type), the east façade (108º) receives insolation during all morning throughout the year, being more intense from December to February, when the sun strikes directly from 05:30 am to 12:00 pm, aproximately. The west façade (288º) receives the afternoon sun throughout the year, specially in the coldest months, from 11:00 am.

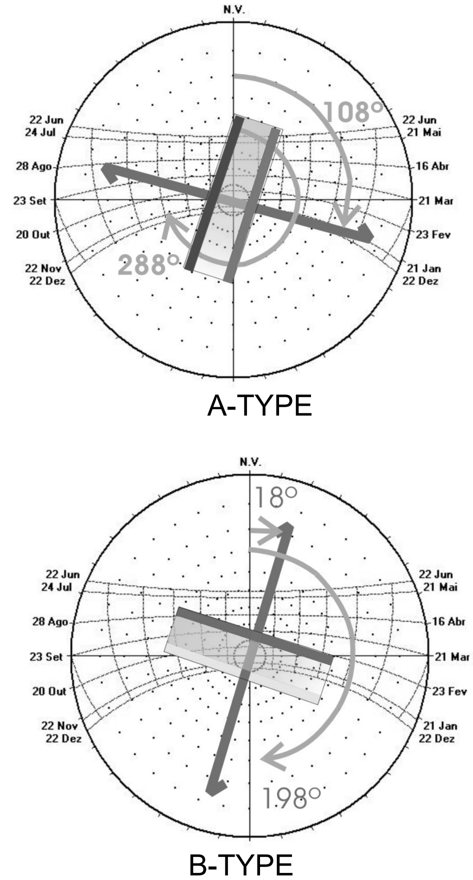

Figure 3: Solar orientations of the studied buildings.

For buildings with orientation 18º/198º (hereafter called B-type), on the south façade (198º), the insolation strikes the surfaces all day long during the summer solstice, receiving direct radiation specially during the afternoon. On the north façade (18º), the solar radiation strikes all day long in some months, mainly in the coldest ones.

Comparing the thermal behavior of the two building types (Table 3), we can observe that in the autumn equinox (03/22), in the summer solstice (12/21) and in the spring equinox (09/22), the A-type receive the highest thermal load, because their façades are more exposed to direct radiation, which does not happen to the B-type, because in its south façade (198º) the radiation incidence is difuse in most part of the year.

Table 3: Solar radiation received on the façades for the buildings with predominant orientations. Source: Luz do Sol software.

Amount of solar radiation (Wh/m2)	Façades orientation			
	A-type		B-type	
	108º	288º	18º	198º
Autumn equinox (03/22)	2391	2899	2255	693
Summer solstice (12/21)	2574	2085	420	1926
Spring equinox (09/22)	3556	4338	3424	1016
Winter solstice (06/21)	2327	4360	6868	611

Only in winter solstice the radiation on the B-type buildings accentuates, due to the fact that the north façade (18º) receives solar incidence all day long, coinciding with the coldest months.

The received solar radiation is intensified due to the fact that the predominant building shape is rectangular, which represents 73% of the studied cases, because different shapes for the same orientation have different behaviors and, for the rectangular case, the largest façades are the ones most exposed to the sun (Figure 4).

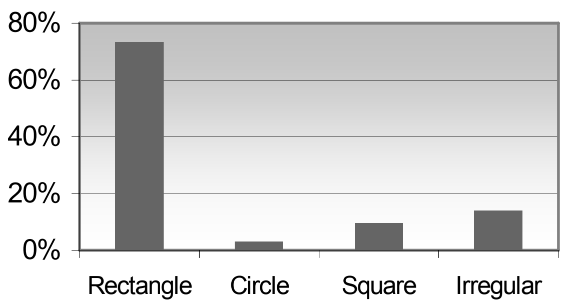

Figure 4: Predominant building shapes

Regarding the height, buildings with 10 floors predominate, corresponding to 17,8%, i.e. 24 of the 135 studied buildings. Following, we can point out, with 16,3%, 22 constructions, the anexes constituted of 2 floors; higher buildings appear in a smaller amount with single examples with 25 to 28 floors, representing 0,7% each, as well as the ones with 14,18, 21 and 22 floors.

Grouping by the number of floors, we have, in a larger amount, buildings with up to 5 floors, with 45,9% or 62 buildings of the whole set analyzed. In a smaller amount we have buildings with more of 22 floors, representing 5,2% (7).

We can notice that higher blocks have a better thermal behavior, because the vertical and the horizontal surfaces are less exposed [9].

Regarding the winds, the building heights only modify them if there is not an adequate distance between the blocks. This analysis will not be made in this work, because it would be necessary a urban survey and a simulation of the wind behavior according to the buildings surface and disposition.

4.2 Opaque and transparent elements

Shape and position, along with treatment solutions, imply a higher or lower thermal load to the building, because the materials are responsible for a share of the heat transmitted to the indoor environment.

Among the materials used on the façades, 63% of the buildings present apparent concrete, several times mixed with others such as: ceramics, painting, stones. They are applied mainly in the blind façades and in small parts of the main façades, where curtain walls predominate.

Concrete is an adequate material due to its thermophysical properties which lead to a delay in the heat incidence on the indoor environment, that will increase with the increase in wall thickness. However, apparent concrete aged with time does not present an adequate absorption coefficient.

It was observed that, of the 135 studied buildings, 65,7% (88) have two glazed façades and 29,9% (39) present 4 façades, generally in agreement to the shape adopted. Of the total number of glass façades (347) in the studied buildings, only 53,3%, i.e. 185 façades, are protected by marquees (30,3% - 56) and shading devices (69,7% - 129). Among the façades protected by shading devices, the west ones present the highest percentage of utilization of solar protection elements, with 45,7% (59), being the south façades the least protected, with 12,4% (16) (Figure 5).

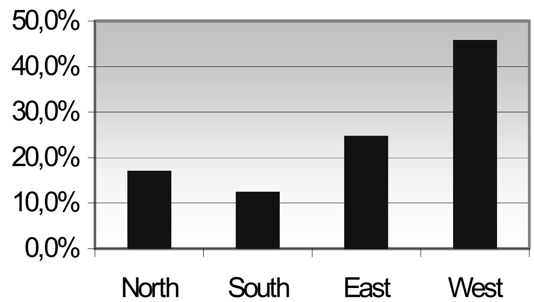

Figure 5: Solar protection percentagem of the façades, according to their orientations.

Vertical shading devices predominate (63% - 81), regardless of the orientation (Figure 5), followed by the mixed ones (22% - 29) and the horizontal ones (15%- 19) (Figures 6 and 7). Of the whole set, 54% are movable (70) and 46% fixed (59), which is a positive fact, because the movable ones allow a greater flexibility in its use, being adjusted according to the user needs. Among the shading devices, the concrete color predominates, with 36% (46), corresponding to the fixed shading devices, because the movable ones present varied colors, being the aluminum the most frequent , with 26% (33).

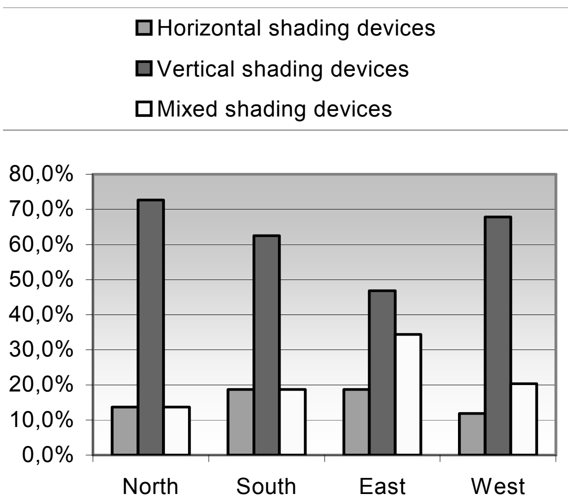

Figure 6: Types of shading devices observed as a function of façade orientation.

Figure 7: Examples of observed vertical and horizontal shading devices.

Taking the discomfort hours [10] and using the Analysis Sol-Ar 5.0.1 software, we obtained a solar chart with the necessary shading period (Figure 8).

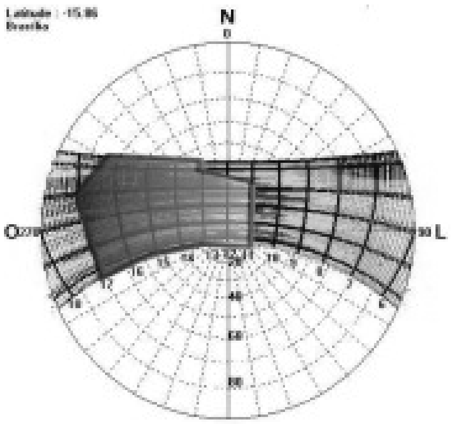

Figure 8: Solar chart with the necessary shading period, shown in dark gray. Source: Adapted from Analysis Sol-Ar 5.0.1 software.

Then, a brief study on the behavior of the different types of shading devices found in the survey as a function of their orientations was made using solar charts. We remark that the data on the shading devices dimensions has not yet been gathered. The shadow masks were generated with possible angulations, considering infinite shading devices, as they are the most frequent. Based on the results, their efficiency in the desired hours were analyzed.

From the graphs produced, it was observed that, for the east façade (108º), horizontal e mixed shading devices are the most efficient, because they protect from 10:30 am. On other hand, the vertical shading device, which is predominant, avoids the sun from 11:00 am from february to september, but does not protect from november to january. On the west façade (288º), the horizontal one also presents itself as the most satisfactory, because the vertical one does not protect at noon in some months, with the protection becoming even impossible from 1:00pm from August to September, for example.

On the north façade (18º), the vertical shading device can be efficient at the discomfort hours at the end of the afternoon, but does not hinder radiation from 11:00 am to 12:00 pm, approximately, in some months. The horizontal shading device is sufficient to satisfy the protection expectations throughout the year, with the possibility of using the mixed shading device as a complement, if desired. On the south façade (198º), the three types present satisfactory protection, being the vertical shading device sufficient to avoid direct radiation at the discomfort hours in the afternoon.

As a solution to solar protection, of the whole set of studied buildings, 85,2% (115) present also glass coloration in several colors, being smoke the most common one (52%-70). According to Santos et al. [11], after a comparative study of the characteristics of transparent materials of same color, it was observed that all the studied materials presented a Solar Heat Factor greater than the Visible Transmission. However, the difference was higher in gray-smoke and bronze materials, showing the low energy efficiency in visual and thermal comfort for hot climates.

Regarding the windows, the ones that open around a horizontal axis predominate, with 97%. As the survey was based only in observations, the opening angles were not measured.

The adoption of solutions regardless the climatic conditions from the early stages of project conception – shape, façade treatment choice and protection elements – lead the users to fulfill their comfort needs by using air-conditioning equipments, which dominate the façades aesthetics, as well as cardboard, aluminum paper and other materials applied on the glass surfaces. It was noticed that 75% (101) of the buildings present window-type appliances or split condensers in their façades (Figure 9), despite the fact that the city presents climatic conditions that make this kind of equipment unnecessary.

Figure 9: Window-type air-conditioning devices on the façades

5. FINAL CONSIDERATIONS

The architect Le Corbusier elaborates several considerations for environmental control which were absorbed by a large number of professionals throughout the world. In Brasília, it was observed that, although there was a initial concern in the urban design with respect to climate and natural aspects, in the public architecture, with modernist influence, artificial methods of environmental control predominate, showing a distance between architecture and climate in most cases.

Regarding the public office buildings, this distance is marked by the incorrect orientation of the buildings, with predominance of the largest façades oriented to east and west, which receive a higher thermal load. This fact becomes more critical due to the predominant rectangular shape and to the use of glass on the façades. The excessive utilization of glass makes the use of the thermal inertia, as indicated in the bioclimatic strategies, impossible.

The idea that the purpose of a window is to illuminate and not to ventilate can be shown by the reduced openings on the buildings. The large glazed surfaces reinforce the corbuserian thought that the building should be treated as an isolated element and that the user should adapt himself to the constructed environment. This is proven by the observation that the users apply cardboard, aluminum paper and install air-conditioning equipment disorderly on to the public office buildings façades, including those that compose the Monumental Axis.

For the buildings where there was a concern in applying solar protection elements, such as shading devices, these were, in most cases, uncorrectly designed regarding their orientation. The same can be said about the solar control films and the colored glass, predominantly smoke, which contribute to an increase in the indoor temperature, because they absorb radiation and transmit it to the indoor environment.

Repetition and inefficiency of the solutions, in most of cases, were clearly seen in the studied samples, even though a deeper analysis of some aspects must and will be made.

From the observations, it can be proven that there is an absence of knowledge and concern about the correct orientation and specification of the protections, which are thougth, several times, only from a aesthetic standpoint. We can remark the importance of a more refined study on the protection elements.

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