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Editors:

Jorge Rodríguez Álvarez

&

Joana Carla Soares Gonçalves

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Severiano Mario Porto's Projects in the North of Brazil:
a Bioclimatic Research About the Amazon Architecture

AYANA DANTAS DE MEDEIROS, CLÁUDIA NAVES DAVID AMORIM

University of Brasilia, Brasilia, Brazil

The architect Severiano Mário Porto is a Brazilian icon. In Amazon region, his projects outstanding characteristics show the local climate potential, bioclimatic strategies, flexible design, cost optimization, renewable materials and regional labour techniques. This paper aims to present the results of an investigation to catalogue the bioclimatic strategies used Severiano Mario Porto design in Boa Vista buildings, focusing on daylighting, shading and ventilation strategies, also evaluated with user's perspective. The method includes documentary survey and case studies selection, the use of morphological diagrams, on-site monitoring, user feedback and computational analysis. The results identify 14 buildings and 4 from these were selected as case studies. Morphological diagrams demonstrate mixed solutions for design, resulting in an expressiveness work for treatment of local impasses. On site monitoring reveals problems related with low illuminance levels and some minimum view quality, due to solar protection elements. The users' opinion demonstrate satisfaction with the luminous environment, although it is always necessary to have artificial lights on. The results of lighting computer simulations, however, shows that the original project have good daylighting levels, before interventions like solar controls glazing with low transmittance. The main strategies used by the architect were… Crossing data, it is possible to conclude that the original projects of Severiano Mário Porto in Boa Vista present good quality in terms of daylighting and shading but, in practice, wasted by inadequate interventions

KEYWORDS: *Bioclimatic architecture; Severiano Mario Porto; daylight; shading; natural ventilation.*

1. INTRODUCTION

In architecture, the relation between building and users is a challenge to design with local conditions. Bioclimatism can be a way to match the challenge to build in a respectful and interactive relationship between man and climate. In this context, questions like daylight, ventilation and user are important aspects to be evaluated.

Regarding the use of daylight, this is an essential resource, with great capacity to transform the users experience in internal spaces into something pleasant [1]. Lighting a room is among the main reasons why architects try to apply daylight to their projects and, in addition, researches demonstrate the human health expectation to better responds for stimulus for natural exposure, mean a strong preference for the use of daylight. However, satisfactory levels of light are variable and individual [2].

About natural ventilation system, it is something defined in the initial design, privileging, or not, the orientation for prevailing winds and using devices that will favour heating or cooling in the environment [3]. In these sense, the passive cooling techniques in buildings are effective and can contribute significantly to reducing the thermal internal gains and can result in good conditions of thermal comfort and indoor air quality, as well as reduced energy consumption [4].

In these sense, the assertive application of resources such as daylight and natural ventilation in architecture needs to be planned, where it is necessary to understand the comfort and climate criteria, realizing the influence of these elements in the built environment, since applying them can cause variations and unwanted behaviour in the building internal microclimate [5].

Thus, buildings in tropical climate are submitted to a dilemma: allowing daylight and natural ventilation to penetrate without solar gains. In this context, shading is one of the most effective resources to combat the discomfort; extensive roofs shadowing openings can be a good strategy [6]. Specifically, in hot and humid climates, like Amazon region, all openings and windows need a system that avoids direct sunlight, through the use of techniques of shading [7].

The shading deals with permanent or temporal, reduction of solar radiation transmitted through the building components. Dominated by need for cooling, solar control devices should reduce solar gains as much as possible, allowing enough daylight and visual contact with the view out. This can be done using external and internal devices, or even using variable transmittance glazing. Besides, researchers indicate that high luminosity of the sky, who causes glare, need control and the vision of the celestial dome must be limited by blockers as architectural frames or, even, through vegetation [6-7].

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So, tropical buildings are typically composed for a light construction, with large openings and shading devices. However, the architecture always had as first paradigm meeting the expectations of users, from the basic aspects of habitability into the aesthetic enjoyment that this shelter can provide to humans. This is a professional challenge, who sometimes prioritize aesthetic-formal values over the performance of the built environment and its functional quality [8].

In these prerogatives, it is proposed the research about projects by Brazilian architect Severiano Mário Porto in the extreme North of Brazil. Icon of Brazilian architecture in second half of XX century, Porto studied in Rio de Janeiro, but his projects detach in Amazon cities, with outstanding characteristics in projects that enjoy the local potential and apply contemporary techniques, using resources like integration and harnessing the local bioclimatic potential, flexible design, cost optimization, renewable materials and regional labour techniques. Throughout almost 50-year career, his professional objective was to find simple solutions, conducted correctly, integrated into the site and well according to the scale of the problems [9].

The focus of this research is about buildings in Boa Vista city, capital of Roraima stated, in the extreme North of Brazil. With a hot and humid typical climate, the city is too close of Equator Line and has two defined seasons: summer (dry) and winter (rainy). According local data, the average temperature rates is around 27°C and relative humidity around 75.9%, being constantly in all the year. Sky condition is dominance for partly cloudy and, about sun exposure, the average is 4,500 Wh/m³ [10].

So, this paper aims to present the results of a master's research, in order to catalogue the bioclimatic strategies used Severiano Mario Porto work in Boa Vista buildings. It is analyse regarding about daylight, shading and ventilation strategies, allied with user's perspective. In this article, the results report about documentary survey and case study selections, morphological evaluation of buildings, apply a monitoring protocol and computer simulation for daylight.

This investigation integrates the work for International Energy Agency (IEA) for Solar Heating and Cooling Programme (SHC), in Task 61, Annex 77 - *Integrated Solutions for Daylighting and Electric Lighting,* Subtask D, who treats about lighting and general aspects, like energy, circadian elements, photometry and users. The aim of Subtask D is develop a monitoring protocol to evaluate the case studies, in different contexts, under a common framework [15].

2. METHOD

To achieve the proposed objectives, were necessary to work in different approaches, since access and treatment of primary data, until the exercise to validate qualitative an architecture. In this sense, applied some steps, aimed at achieving result, and for conclusions, analysed of data with cross studies, with attention to the bioclimatic elements present in the select projects, especially about daylight, shading and natural ventilation.

2.1 Documentary survey and case study selection

The first step is based in search for information in documents without scientific treatment, using materials that lack analytical procedures, consultation primary sources. Accordingly, the documentation of Severiano Mário Porto's projects was consulted. This material is part of Research and Documentation Centre, of the Faculty of Architecture and Urbanism of the Federal University of Rio de Janeiro.

After, began the selection of case studies. For a representative analysis, the focus was to identify the buildings with best conservation status in relation to the original project. So, applied the Brazilian standard about Valuation of Goods of Historical and Artistic Heritage [11] as an instrument. This standard parameter analyses the original project and classifies buildings according the state of conservation and integrity, in order to appoint it like preserved, restored or uncharacterized.

2.2 Morphological diagrams

To identify bioclimatic strategies in case studies, the methodology proposed are morphological diagrams. The instrument is a document for qualitatively evaluates architectural projects. It is apply with objective to composition a repertoire of architectural typologies and can be used in early stages of project and in exist building, in order to verify possible aspects that can still be optimized [12]. The selected diagrams study issues related to daylighting [12] and natural ventilation [13].

The morphological diagrams are compose into three moments: local place, building and environment. Through technical pieces, such as location, floor plans and cuts, it is possible to develop results in a report that presents the architectural solutions found.

2.3 Monitoring Protocol

The on-site verification of the lighting condition was determined using the guidelines of the Monitoring Protocols of the International Energy Agency [14-15]. According to IEA [15], protocols are instruments with credit and support, where a big amount of information is collected and made

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available, in order to summarize this in an objective and easy to understand.

These protocols are integral part of research by the IEA-SHC Task 50 [14] and Task 61 [15], both about lighting with energy aspects. The "*Monitoring protocol for lighting and daylighting retrofits*" - Task 50 [14] and the "*A monitoring protocol to evaluate user-centered integrated solution*" - Task 61 [15] discuss procedures to verify the lighting condition in an environment. The mentioned documents establish measurement mechanisms on-site that have a common structure. In the developed dissertation, the dimensions of study used were photometry and users, with photometry and view out analyses and questionnaire survey.

2.3.1 Photometry and View Out

The photometric dimension includes environmental and spatial aspects of lighting. According to consolidated surveys, some of the quality indicators are illuminance and view out [15]. The protocol suggests the separate measurements with only daylight, only artificial light and both combinate, in order to approximate the measured results to the real condition. In this research, data were collected for the analyses about: reflectance of surfaces, illuminance average, illuminance on the task, uniformity, and quality of the view out.

For the average illuminance verification, the protocol proposes a grid in place, which divides the room in small measurement areas. The method consists of a measurement points that must be drawn from the central axis of the window, towards the back of the room. A first measurement is made at 0.5m from the window, and then from 1.0m to 1.0m [14]. The capture of illuminance must be determined at 0.80m above the ground, with a luxmeter. These grid measurements assist in analyses of distribution of illuminance, illuminance on the task and uniformity of light. Simultaneously, the measurement of the global diffuse external illuminance is performed, for every 5 minutes. This measurement takes place outdoors, without obstruction of direct solar radiation, shading the external luxmeter cell with a small disc and recording the sky condition on time.

To verify the quality of view out, the monitoring protocol indicates the method proposed by European Standard for Daylight in Buildings [16]. This document present that the aesthetic value of a user's scene is related to complexity, maintenance, temporal aspect, among others. The composition can be examined with a photograph of the view out, taken from the landmarks within the environment (for this study, the photos was taken in centre of the rooms). For a good composition, the elements generally appreciated should not be fragmented, and a balance between the left and right sides of the image must be guaranteed. In addition, information for location, weather, climate, surroundings and the flow of people outside is also important.

2.3.1 Questionnaire survey

The questionnaire applied is based on the proposal of International Energy Agency (IEA) [15], from April 26, 2018 version. This document was translated and adapted to investigate user´s opinion regarding daylight and well-being conditions in the study case. Thus, the resulting document consisted of 50 questions, divided into 4 sections, namely: section 1 - general data; section 2 - social and physical climate; section 3 - user's experience with lighting; and section 4 - user's interest in building. It consisted of 4 pages, with predominance of objective answers.

2.4 Computer simulation for daylight

The computer simulation of daylight was modelling by DesignBuilder, version 6.0, and Radiance program. The idea was to cross these step results with data from morphological diagrams and measurement on site, simulating the original condition on Severiano Mario Porto design, without some recent changes in space, like addition of films on glass and internal layout.

3. RESULTS

3.1 Documentary survey and case study selection

According to the documentary survey, Severiano Mario Porto developed 14 projects in Boa Vista city. The original records are outdated and without any characterization of the current state of buildings. This information was updated and organized.

The state of conservation of Severiano Mário Porto's buildings in Boa Vista was the main criterion for choosing case studies. The cases that interests this research are those in which the project intention was preserved or partially preserved. From the 4 case studies selected, 03 are schools, partially preserved, and 01 is an institutional building for public use (Figure 01), with a good state of preservation.

Figure 01 – preserved case study

These 04 case studies were analysed with morphological diagrams; the on-site monitoring was

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performed in the institutional building, in better stage of preservation (Figure 1), together with questionnaire survey and daylight computer simulations.

2.2 Morphological diagram

The morphological diagrams from 4 selected case studies appoint the common elements used in project for Severiano Mário Porto in Boa Vista: buildings with façades of low reflectance and specularity, high opening rates on the façades (between 25% and 50%); façades not uniform in relation to solar orientation; internal spaces with adjacent cross ventilation and use of pivoting windows (rotating on the vertical axis); and brises-soleil, cobogos, eaves and marquees, pergolas, and vegetation as elements of sun protection.

On the roof, all buildings have a robust eaves, with more than 2 meters, where this advance function as a horizontal element of shading. In schools, the corridors are used as structure and addition to sun protection (Figure 2).

Figure 02 - corridor on a Severiano Mario Porto school, east facade

With brises-soleil (Figure 1), it is possible analyse that the solutions, horizontally and vertically, provide protection at times when the solar path is most critical, close to midday (Figure 2). Although the often excessive sun exposure in Boa Vista, studying with solar map, it is possible verify how the structures show good shading angles, allowing the penetration of heat daylight until 9 am in the Northeast façade and after 3 pm on the southwest façade (a critical orientation).

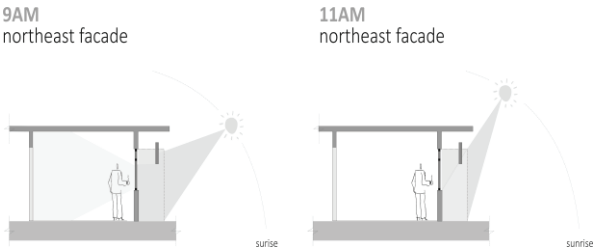

Figure 03 - solar path in case study room

The organization of the building's volumes also enables self-shading. In the case study in better conservation condition, the building is envelope with fixed brises that also collaborate as a solar protection element (Figures 1 and 3), without, meantime, compromising the view out.

Regarding window frames, there is a notable design intention in the use daylight and ventilation in the architect choices, with windows and structures designed in order to optimize the entry of daylight and circulation of the winds with the use of pivoting windows, lamellar openings and translucent surfaces. In classrooms, the distribution of frames in bilateral way, on opposite faces and with different heights, helps in cross-ventilation, indicated for the local climatic context.

3.3 Monitoring Protocol

3.3.1 Photometry and View Out

For the systematization of data from the application of the IEA Monitoring Protocol [15-16], it is worth commenting on some information observed. The first one is about windows in the building, received adhesive film blocking around 50% of direct solar radiation, which strictly interferes with the level of luminosity obtained through on-site measurements. Another comment is about rooms internal organization, flexible. In the investigated case study, the furniture itself blocks the openings and view out sometimes is a factor that compromises access to daylight and better lighting conditions in the workstations. However, they provide privacy and are not subject of complaints among users.

Regarding the lighting on task, the rooms with Northeast orientation facade show more desirable conditions as the rooms in the Southwest. In general, the results of the measurements in grid demonstrated there is not a satisfactory level of average illumination, below for the Brazilian lighting standard levels. When combined, daylight and artificial light, offer a good average of illuminance and even achieve good levels of uniformity. In all aspects analysed, the rooms on a higher floor offered better lighting conditions.

When analysing the quality of the view out, it is important explain that the entire building is envelop for fixed brises, in concrete sheets, for shading. However, internally, these elements do not compromise the contact with outside. Theirs modulation are strategically fitted in order to converge with the structure of the frames, which allows a continuity in the view out perceived, by the users.

All studied rooms have a high degree of view range (with an angle greater than 50°), a quality factor, in addition to a good indicator of external distance. Nevertheless, the number of layers varies from minimum to high, determining the general

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quality of the view out analyses. The only room with low quality of the view out (due to the minimum number of layers) is located on the ground floor and oriented to an internal atrium of the building, limiting the visual layers.

3.3.1 Questionnaire survey

The application of the questionnaire resulted in 37 valid answers, that represents 20% of total population of the building. In general, the satisfaction with the built, 27% are satisfied, while 29.7% are neutral and 32.4% very satisfied

The levels about daylight satisfaction on your work plan, 27% are very satisfied, while 16,2% are very dissatisfied, and 21,6% in a neutral stage. About how apply daylight in your workstation, 86.5% answered never work using only natural light (highest percentage among all surveyed items). This is an interesting response when cross with the answers about lighting preferences, and the satisfaction rate with the natural light achieved on task.

About view out, the information are: 32.4% very satisfied, while 29.7% very dissatisfied and 37.9% not satisfied and not dissatisfied. In rooms with daylight access restriction, this discontent is higher.

3.4 Daylight Computer simulation

Regarding Severiano Mario Porto original design, the calculation of the Spacial Daylight Autonomy – sDA, verified that all the studied rooms show an expressive potential of daylight illuminance values, superior to 500 lux, in a good part of the year. These appoint that the original project has a better daylighting condition that your actual stage. The studied rooms have big part of evaluation plan with more than 500 lux, in more than 60% of the hours of the year. Only one simulated room, due to its internal location, has an unfavourable condition, with less than 40% of the hours of the year meeting this requirement.

About the glare probability, the levels of Annual Sun Exposure - ASE, greater than 2000 lux, was around 25% of the hours of the year. Without any apply of internal blocking device, such as the existing blinds, the occurrence of values above 2000 lux only appear in the areas close to the windows, in all rooms, representing a small area.

As for the Useful Daylight Illuminance - UDI, in an interval between 100 and 2000 lux, it is clear that, originally, there is a great vocation to use daylight in all verified rooms. The only place that needs attention are those close to the windows, with potential for glare, but with reduced area. In general, the potential for using daylight in all rooms is very satisfactory.

4. CONCLUSION

Proposing and performing a multimethod analysis on Severiano Mário Porto projects in Boa Vista city, the research conclusions converge to crossing data. Firstly, rescuing the understand that bioclimatic architecture brings man and environment closer together, it is possible to analyse that the strategies employed by Severiano Mário Porto, in Boa Vista projects, guarantee a bioclimatic bias in his design practice. This study admits that there is, in fact, a preponderant concern of the referred architect with the issue of shading in projects for the Amazon context.

Morphological diagrams demonstrate that the found answers are mixed solutions that, combined, such as form, coverage, hollow elements, orientation and set of frames - result in an expressiveness work for treatment of local impasses. The investigated projects have significant potential, in search of passive solutions for daylight, shading and natural ventilation, with the replicability of some elements employed in all case studies, like brises-soleil, cobogos, large eaves and vegetation as elements of sun protection.

For verification with a representative case study, in better state of preservation, through on-site visits, application of a monitoring protocol and consultation with users, some aspects were obtained about the real condition of use of the building and the changes imposed on the original project (such as applying window films). It was noticed that, in practice, in terms of daylight, the case study analysed does not present satisfactory conditions of illuminance, whether in average illuminance or on task plan. This observation also happens when checking the combined systems, natural and artificial light, which an unsatisfactory lighting performance. According Brazilian standards, none of the measured rooms offered a good lighting condition, in all the verified variables (illuminance average, on task and uniformity).

About view out of the windows, the results showed medium and high quality, with the number of layers being decisive. Of the 4 studied rooms, 1 presents with high quality of the view out, 1 with minimum quality, but, in general, all have high reach and high external distance as positive aspects of contact with the external environment.

About users' perspective as an element of investigation, in the representative case study, responses corroborated with some these results: the majority mention a little availability of daylight in their workstation and the respondents show there is no use only daylight as a source of light for your work. However, levels of satisfaction with general space are polarized but point to a positive majority. Satisfaction

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with the view out and other qualities of the space may justify this fact.

For the same rooms where the real conditions of use were verified, with monitoring protocol, data regarding computer simulation of daylight are given. They indicate the potential for daylight use in original design. The results showed good levels of illuminance for daylighting, without presenting a high probability for internal glare. This concludes all the concern with shading and sun protection in Severiano Mário Porto's projects, in their original condition. Even though developed without the technology around software and computer simulation, they were designed to achieve a satisfactory performance for lighting with natural light, without propose too high thermal internal gains for direct solar radiation.

However, whether through the results of the measurement or the responses of users, it is concluded that the good levels of daylighting it is not, in fact, the reality of the studies rooms today, with a discrepancy between the original design intention and the existing building. This fact can be attributed to the modifications made to the original design, like the addition of films and the reduced of light transmission of the glasses. An unanswered question in this work is the motivation for adding these films to the original project.

Conducting the research and visiting on site Severiano Mario Porto buildings in Boa Vista city, the contempt for many of the design intentions was noticed. An example, closing the lamellar frames in schools, clearly indicates this fact.

Its assertive understand some demands for cooling, today, the rooms with artificial equipment. The extreme conditions of Amazon climate admit this option. But the wrong way to interfere in the space, reaches not just in thermal condition, they have implication in daylighting conditions too, clearly an original design presuppose.

Although designed to optimize the use natural ventilation and daylight, as well as promoting shading and sun protection for internal structures, these builds received interventions that sacrificed some of their original intentions. This is the case of the total closure of the shutters in the classrooms of the investigated schools, the arbitrary replacement of the original frames and the application of films on the windows. Here, the interventions carried out and necessary are not condemned, without the zeal to maintain the potential of the projects.

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