Light and shadows in an Amazon building

SHC
SOLAR HEATING & COOLING PROGRAMME
INTERNATIONAL ENERGY AGENCY

Challenges to integrate daylight and solar protection elements in an iconic building of the Brazilian modernism

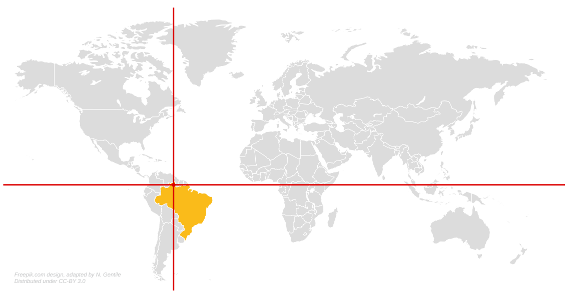
In a representative Amazon building daylight use and solar control elements are examined. Occupants are satisfied with the indoor space, despite some changes done to the original design. Computational simulations suggested good daylighting design overall, with little risk for glare occurrence, as in the intention of the original design.

The project

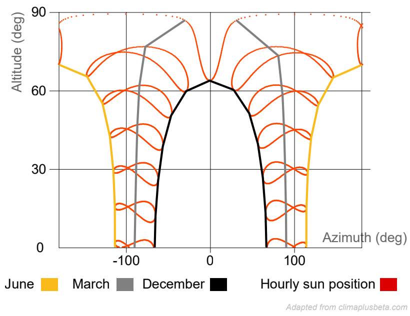
Forum Sobral Pinto (Figure 1) is an important building in Boa Vista City, capital of Roraima state, extreme North of Brazil. Located close to Equator line, immersed in Amazon Forest, the place serves to the local judiciary authority. The Forum Sobral Pinto was built in 1979, designed by Severiano Mário Porto - an icon of Brazilian modernism architecture -, internationally recognized as the “architect of the Forest ”or the “architect of the Amazon”. Elected man of the year by the French magazine *L’Architecture d’Aujourd’hui* in 1987, he developed in the Amazon a design with its own identity, using resources such as integration and use of local bioclimatic potential, with focus on cost optimization, renewable materials, and regional techniques. In the Forum Sobral Pinto building, Severiano Mário Porto applied bioclimatic strategies – like fixed solar shading elements - with impressive quality, while the limited depth of the building still allowed for abundant daylight penetration.

Figure 1. Forum Sobral Pinto building.

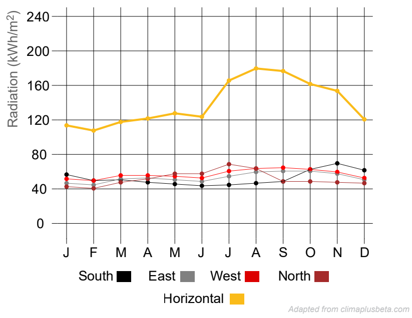
The building has an area of 5686 m^2 distributed in four floors (including an underground one). All the windows are oriented Northeast and Southwest, with fixed concrete elements used as solar shading (Figure 2). Originally, these windows had a single glass, but solar and light control films were added later for privacy and security. The windows films are of smoked type, with 50% of light transmittance. Such modification represents a major change in the original daylighting design by Severiano Mário Porto.



Location: Boa Vista, Roraima, Brazil
-11.99°, -84.14°



Sun path for
Boa Vista, Roraima, Brazil



Global horizontal and vertical radiation for
Boa Vista, Roraima, Brazil

IEA SHC Task 61 Subtask D

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Figure 2. Forum Sobral Pinto, Northeast Façade.

Figure 6. Workstations in Office 2.

Sun radiation in the Amazon context is often intense; the design from Severiano Mário Porto in this building includes fixed horizontal and vertical frames, providing sun protection at critical times, with good shading angles (Figure 3). In this building, solar elements block solar radiation after 9:00 am in the Northeast façade and until 3:00 pm on the southwest façade. The climatic context challenges the architectural project to optimize daylight in indoor spaces, without compromising thermal comfort of the building. Therefore, shadows and sun protection are an important strategy to keep environmental quality in the Amazon building, and to minimize energy use.

Monitoring

The first field monitoring was performed on 28th and 29th August 2019, around 11:30 am. The sky condition was partly cloudy, with global illuminance values between 13800 lux and 28700 lux. A second field monitoring was done on 2nd and 3rd January 2020, at the same time as the first monitoring. The global illuminance ranged between 7100 lux and 16400 lux, with overcast sky conditions. The measurements were performed in representative offices on ground floor and 2nd floor, in Northeast and Southwest façades (Figures 4, 5 and 6).

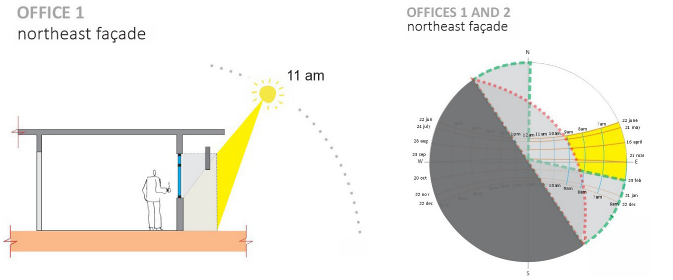

Figure 3. Section and solar chart showing solar protection elements in Northeast façade.

Figure 4. Plan of the building floors, with monitored offices.

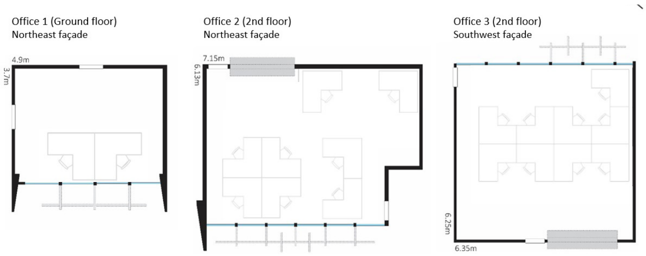

Figure 5. Plan of monitored offices.

The investigated aspects were illuminance (grid based and on task), uniformity, directionality, reflectance, view out, circadian potential, energy use, and users' perspective.

Energy

The electric lighting system consists of LED T8 luminaires 2x18W, providing lighting at 6500K and an on-off system. In the building, there is no separate energy meter for lighting, so the calculation of energy use was made based on the European Standard EN15193-1:2017. The Lighting Energy Numeric Indicator (LENI) average in three measured offices was 16.84 kWh/m²yr, varying between 20.10 kWh/m²yr in Office 1, 16.70 kWh/m²yr in Office 2 and 13.70 kWh/m²yr in Office 3.

Photometry

The field monitoring was done for two different conditions: daylighting and day+electric lighting (usual condition). Table 1 present some of the results.

Regarding illuminance, in both monitoring with partially cloudy sky and overcast sky, the workstations did not reach the minimum illuminance levels with daylight only,

Table 1. Measured illuminance and uniformity.

Monitored room	Source	E_{avg} (lux)	E_{max} (lux)	E_{min} (lux)	Uniformity (U_0) E_{min} / E_{avg}	E_{avg} (lux)	E_{max} (lux)	E_{min} (lux)	Uniformity (U_0) E_{min} / E_{avg}
		28-29 August 2019 (partly cloudy)				2-3 January 2020 (overcast)			
Office 1 (Northeast)	Daylight	58	118	21	0.36	35	75	5	0.14
	Day + Electric	657	1018	155	0.23	639	1050	245	0.38
Office 2 (Northeast)	Daylight	57	210	8	0.13	62	180	16	0.38
	Day + Electric	517	875	113	0.21	470	880	150	0.31
Office 3 (Southeast)	Daylight	57	455	10	0.17	115	500	33	0.28
	Day + Electric	354	620	130	0.36	461	1090	160	0.34

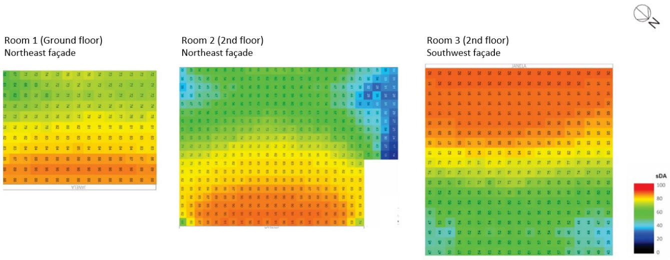

Figure 7. Spatial Daylight Autonomy (sDA).

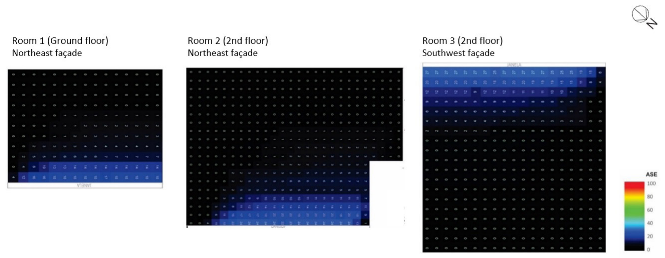

Figure 8. Annual Sun Exposure (ASE).

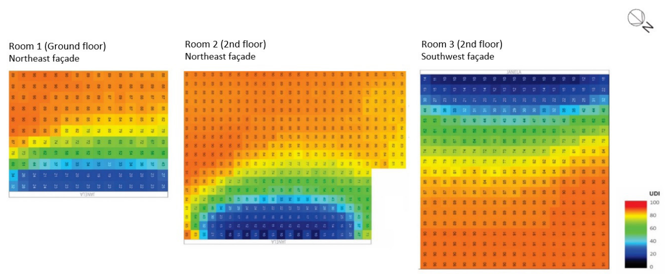

Figure 9. Useful Daylight Illuminance (UDI).

Table 2. View out quality according to EN17037:2018.

Office	Criteria	Results	Rate
1	Horizontal sight angle	104°	High
	Distance of view	> 50 m	High
	No. layers	2	Medium
	General view rate		***Medium***
2	Horizontal sight angle	97°	High
	Distance of view	> 50 m	High
	No. layers	3	High
	General view rate		***High***
3	Horizontal sight angle	90°	High
	Distance of view	> 50 m	High
	No. layers	2	Medium
	General view rate		***Medium***

Figure 10. View out in Office 2.

which should be 500 lx according to the Brazilian standards. Most probably, this was due to the very low visible transmittance of the control films applied to the existing glazing. Therefore, the field monitoring was complemented with computer simulations, where the daylighting performance of original design (without solar control films) was tested. The simulations were performed with the software DesignBuilder 6.0 and Radiance. The original condition of the project was considered, with simple 6 mm glazing, with 89% light transmission (instead of 50%, with solar control films). The following daylight performance metrics were simulated: Spatial Daylight Autonomy (sDA), Annual Sun Exposure (ASE) and Useful Daylight Illuminance (UDI). Figures 7, 8 and 9 present the results.

Spatial Daylight Autonomy (sDA) shows that in all offices illuminance values are higher than 500 lux for most of the year. Regarding glare risk, the levels of Annual Sun Exposure (ASE) higher than 2000 lux are reached only for 25% of the working hours, with open blinds. The occurrence of values above 2000 lux is only in the areas close to the windows, representing a small area. Useful Daylight Illuminance (UDI), between 100 and 2000 lux, shows a great vocation to daylight use in all simulated rooms, in the original design condition. Close to the windows, the daylight illuminance is sometimes above the UDI threshold (2000 lux), which explains the low UDI percent in such areas.

Regarding view out assessment, the evaluation follows parameters proposed by EN 17037 Daylight in buildings (CEN, 2018). All offices have a high view range, a good external distance but the number of layers varies from medium to high, determining the general quality of the view in the studied offices: Medium in two and High in one. Figure 10 illustrates the view out from one of the office. In Figure 10, the effect of the solar control film can also be appreci-

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ated.

The results for the view out are presented in Table 2.

Circadian potential

Equivalent Melanopic Lux (EML) values were calculated using the Lucas spreadsheet using the approximate method via measured illuminance levels. The results were

Table 3. Measured Equivalent Melanopic Lux (EML).

	Workstation	08/10/2019 (partly cloudy)	10/11/2020 (overcast sky)
Office 1 (Northeast)	1	395	237
	2	233	253
Office 2 (Northeast)	1	379	**197**
	2	316	403
	3	292	261
	4	252	**150**
	5	**110**	**103**
	6	284	245
	7	221	**69**
	8	**103**	**66**
Office 3 (Southeast)	1	**123**	**111**
	2	**126**	**170**
	3	**123**	**150**
	4	**79**	**123**
	5	**87**	**111**
	6	**103**	237
	7	**158**	**134**
	8	**32**	**96**
	9	284	229

benchmarked against the Circadian System criterion of the WELL v2 building standard. Results are showed in Table 3. Considering that 75% or more of the workplaces must have at least 200 equivalent melanopic lux according to WELL v2, only Office 3 does not meet minimum requirements. Since the control film filtrates the incoming daylight, it would be interesting to test further the resulting melanopic lux when measuring the actual Spectral Power Distribution of light.

User perspective

A questionnaire was used to investigate users' opinion regarding daylight and well-being conditions in the building. The building hosts 260 employees, and 37 valid responses were obtained. Roughly, half of the respondents were women; 27.3% of the respondents were under 30 years old, 19.6% between 30 and 40 years old, 44.7% between 40 and 50 years old, and 8.4% over 50 years old. Regarding the general impression, almost 60% of users were satisfied or very satisfied with the space. However, only 44% were satisfied with daylight, probably because the addition of solar films reduced illuminance levels. In fact, 86% of users answered that they could never work using only daylight. Regarding view out, the answers were more scattered: 31% were very satisfied, 34% tending for neutral and 31% very dissatisfied. Here is important to note that solar control films tend to distort colours and this can also influence the user's perception.

> ***" Too much electric light in my workstation with just a little of daylight coming from the windows. I also notice a 'conflict' between electric light and computer monitor light. "***

> ***"Artificial lighting is widely used. It's possible save energy. "***

Lessons learned

In terms of daylighting, when applied the monitoring protocol on the usual condition of the case study, the illuminance values are not satisfactory according to Brazilian standards (average, on task and uniformity). Regarding the exterior view out, results showed medium and high quality, with the number of layers being decisive. Analysing the circadian potential, either with only daylighting or with the day+electric lighting combination, the results are satisfactory in most of monitored rooms. When considering the users' perspective as an element of investigation of these environments, the answers corroborated with some of these results: most mention that there is little daylight availability in their work plan and the totality of the respondents stated that they do not use only daylighting for work. However, satisfaction with space are polarized and point to a positive majority. Satisfaction with the view out and other qualities of the space can justify this fact.

The addition of solar films, due to security and privacy needs, reduced the luminous transmission of glazing from 89% to 50%. Lighting simulations with original condition without solar films shows the potential for daylight of original design. The results show good illuminance levels, without glare. As a lesson learned, retrofit measures should be selected carefully and coherently with the intention of the original design. In this case, for example, Severiano Mário Porto's original design for Boa Vista, - with fixed solar control elements and a thoughtful building shape, achieved a satisfactory daylighting performance despite all concerns with sun protection and shading for buildings in the Amazon. However, the later application of solar films for privacy reasons partially spoiled an impressive daylighting design.

Further information

Medeiros, A. D. (2020). *A arquitetura de Severiano Mário Porto na cidade de Boa Vista: um olhar com enfoque bioclimático (Severiano Mário Porto's architecture in Boa Vista city: a bioclimatic perspective)*. Master thesis in Architecture and Urbanism Programme, Faculty of Architecture and Urbanism, University of Brasilia, Brasilia, Brazil

Acknowledgements

This work was supported by the **National Council of Scientific and Technological Development (CNPq)** of Brazil. Support on site: Forum Sobral Pinto Management
Special thanks to **Jorge Jaworsk** (building manager)