Building Simulation

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BRISE SOLEIL - CLASSICAL ELEMENTS OF TROPICAL MODERNISM

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ABSTRACT

Horizontal and vertical brises soleil are dominant elements in the modernist tropical architecture. It was the obvious answer to the question on how to adapt the modernist architecture, developed in moderate climates, to the tropical climate with its particularly high solar radiation.

Buildings for example like, the buildings of the Central University of Venezuela in Caracas (Carlos R. Villanueva, 1945 – 1953) or the ministry of education and culture MEC (Lúcio Costa, Le Corbusier et al. 1943) [1] in Rio de Janeiro, make intensive use of these elements.

With the widespread introduction of air-conditioning systems and special glazing these typical elements of tropical modernist architecture vanished. Simultaneously the energy consumption of tropical buildings rose dramatically, due to the facades now widely unprotected from the high solar radiation.

Using Radiance [2] instead of time and money consuming real measurements, the brise soleil system of the MEC in Rio de Janeiro was evaluated, simulating three different angles of the horizontal blinds, which are possible by the existing mechanism. The results were compared with today's demand on lighting in office spaces.

The idea was to prove the relevance of a relatively old technique, implemented in a world-wide famous milestone of modern architecture, for contemporaneous energy efficient architecture.

INTRODUCTION

The MEC can clearly be seen as one of the most important buildings of the tropical modernism world-wide. This milestone in the history of architecture was also the starting point for many young Brazilian architects, who would have an enormous influence in the Brazilian and international modernist architecture later on. Receiving a consultancy by Le Corbusier, who visited Rio de Janeiro in 1929 and again in 1936, a group of young architects, headed by Lúcio Costa, embraced the ideas of the modernism and designed a – what we would call today – a bio-climatic building: the office floors are cross ventilated by huge windows in the south and in the north façade. For this purpose the upper half of the windows can be lowered with a winder mechanism; the east and west facing facades of the office tower are narrow and without windows; the south façade is fully glazed and, in some floors, equipped with wooden venetian blinds to reduce direct solar radiation in the mornings and in the evenings of the winter months. It also protects against strong diffuse radiation of the tropical overcast sky, which is in average approximately two times as strong as calculated by CIE Overcast Sky [3]; fixed, concrete vertical brise soleil and movable, iron horizontal blinds on the north façade to keep out direct solar radiation. The importance the architects gave to the flexibility of the horizontal blinds in order to adapt the façade to different sky conditions can be seen in some of the very first sketches of the building concept, exhibited in an exposition of the buildings history in the MEC.

The results of these devices are still visible today: the offices work without air-conditioning and the users are satisfied with the prevailing indoor climate.

Observing the building on different days with different sky conditions, one can see, that the artificial lighting is always on. On the other hand the horizontal blinds, which can be easily fixed in three different positions with a mechanism, are always in the same semi-closed position. Therefore the idea of this simulation cycle was to verify the effectiveness for daylighting of all three different positions.

The Radiance-simulations were used to get to a qualitative basis for a quantitative evaluation of a design idea more than 60 years old and never used

after implementation (as photos of the last 6 decades prove).

METHODOLOGY

Rio de Janeiro is located on a latitude of 22,5 ° South and a longitude of 43,1° West, it has a very good external daylighting offer with 20,046 hours of sun per year, well distributed over the whole year (see table 1) [4]. Main concerns are a very high solar radiation of1679 kWh/m² year [4].

Table 1: Average daily sunshine in hours

Jan	Feb	Mar	Apr	May	Jun
6.02	6.79	6.29	5.60	5.46	5.49
Jul	Aug	Sep	Oct	Nov	Dec
5.74	4.70	4.40	5.12	5.56	5.10

The maximum value for CIE clear sky and sun of 114000 Lux for the 21st of December and 60.000 Lux for the 21st of June where confirmed with a class 2 illuminance meter. The values or CIE intermediate sky & sun were measured for CIE intermediate sky without sun (approximately) . This distortion is due to the generally higher illuminance in tropical countries. The daylighting situation was checked for three times a day: 9 am, 12 am and 4 pm, which can be considered as core office hours.

Table 2: Illumination Values on Different Day Times at Solar Max. and Min. Dates; confirmed through handheld class 2 measurements by the author (variation < 5%)

	9 am	12 am	4 pm
CIE css			
21.06.	34045 lx	60231 lx	21344 lx
21.12.	64358 lx	114007 lx	50017 lx
CIE intermediate with sun			
21.06.	13086 lx	21201 lx	8588 lx
21.12.	21880 lx	25582 lx	18594 lx

For the simulation the 15th floor was used as a base. The horizon is not obstructed between 9 am and 4 pm. The whole office floor is one room, divided by wooden partitions, which are 1,8 m high. These divisions were not considered in the simulation. The north – south extension of the office space is almost exactly 20.0 m, the east west extension is 67.7 m. For the simulation the north – south extension was used exactly, while the east – west extension was reduced to 37.5 m in order to avoid unnecessary calculation time. The space is 3.89 m high. The degree of reflection of the walls and the ceiling is 0.85, of the floor 0.54.

There are no venetian blinds considered on the south façade, due to the real situation in the 15th floor.

4 reflections were calculated.

The illuminance level is calculated for a work place altitude of 0.72 m. The points of the calculation grid are every 2.0 m in the depth of the room and every 2.0 m in the width. The grid starts 1.0 m from the north façade and ends 1.0 m from the south façade. Due to the relatively big distance between the measurement points it was necessary to check the different situations visually with rpict (rpict is a preview tool in the Radiance ambiente). In two situations a direct solar radiation in the office space were found, one also detected through the measurement point (fig. 16 & 17).

The reflection of the vertical brise soleil is 70 %, the reflection of the horizontal brise soleil is 20 % .

The outside ground reflection is 20 %, reflections from other buildings are not considered.

Observation: the thermal aspect of the results as well as the luminance aspect are part of the study and are under preparation for future publishing.

Figure 1: 3D - partial isometric view of the north façade with vertical and horizontal brise soleil

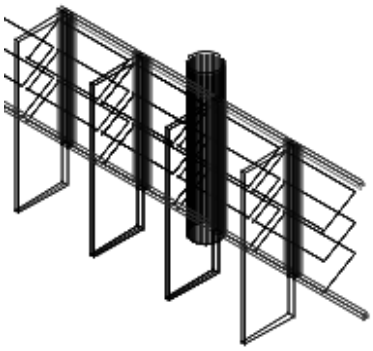
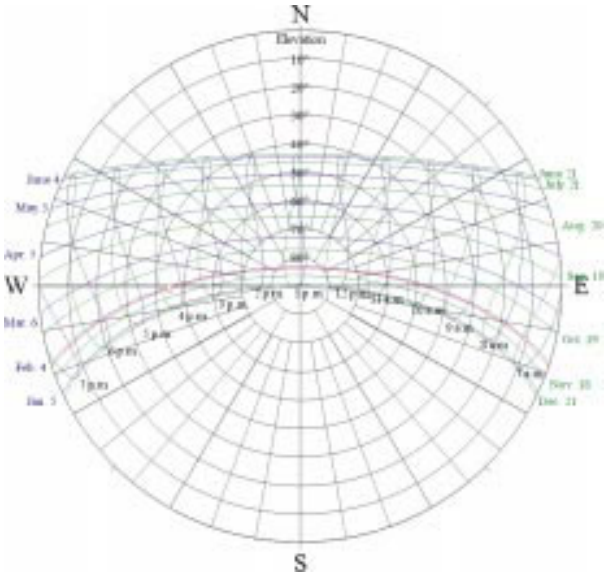


Figure 2: sun path for Rio de Janeiro, GMT – 2.00 (summertime)

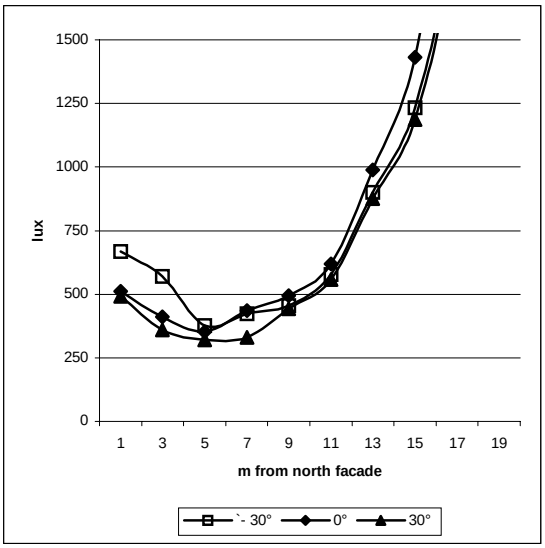


RESULTS:

The demonstration of the results has partly to be split due to the wide range of illumination values created by the different positions of the horizontal brise soleil. The first part of the tables (a) shows the full range, while the second part (b) concentrates on the comfort range between 0 and 5000 lux. The Brazilian norm NBR 5413 for illumination foresees 500 lux as minimum for the general illumination of office spaces, recommends up to 2000 lux in class B (general illumination for working space) and promotes 2000 to 20000 lux (the highest value for surgical operations) as additional illumination for difficult visual tasks.
The results shown are the maximum values from the two center grid lines. Due to the column, there might be shadow falling on one of the measurement points. In that case the grid line without shadow was considered, due to the special situation in the tropics: the problem is an offer of very high illumination values, causing glare and thermal discomfort. The really important area is between the north facade and a depth of 10 m, where the brise soleil have the most impact. The area from the middle of the room to the south façade is dominated by the fully glazed south façade. Due to its important impact on the overall daylighting of the office space it had to be considered, anyway.

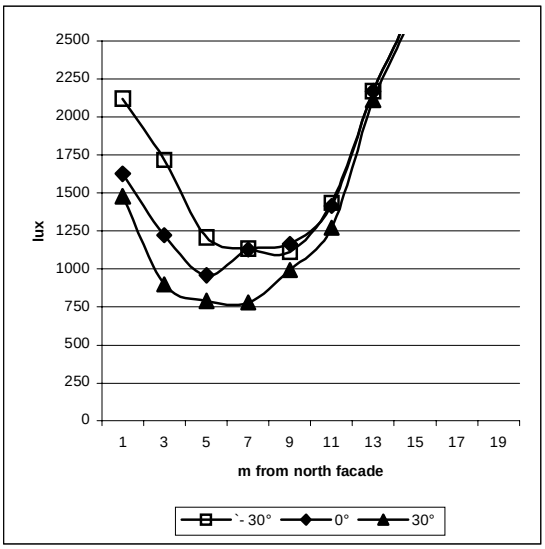
1) Results of the three possible positions for the 21st of December, 9 am (figure 3):
   At 1.0 m from the window, the position –30° improves the daylighting around 32%, at 3.0 m around 59%, at 5 m around 17%, at 5.0 m around 28%, at 9 m around 3%. The position 0° does not improve the daylighting significantly.

Figure 3: Results of Full Range/Comfort Range, 21st of December, 9 am, CIE clear sky sun



2) Results of the three possible positions for the 21st of December, 12 am (figure 4):
   The daylighting of position 30° is already quite good. Both alternatives, 0° and –30° rise significantly the daylight offer in the office space, without causing glare and thermal discomfort. This additional daylight offer may be very welcome in the case of partitions being used.

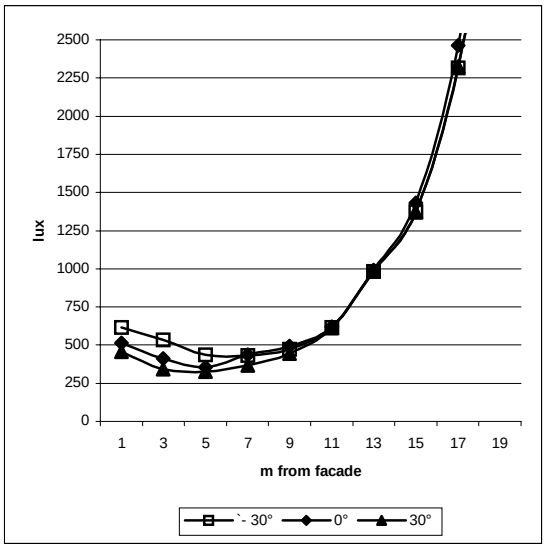
Figure 4: Results of Full Range/Comfort Range, 21st of December, 12 am, CIE clear sky sun



3) Results of the three possible positions for the 21st of December, 4 pm (figure 5):

At 1.0 m from the window, the position –30° improves the daylighting around 34%, at 3.0 m around 56%, at 5.0 m around 34%, at 7.0 m around 18%, at 9 m around 7%. The position 0° does not improve the daylighting significantly.

Figure 5: Results of Full Range/Comfort Level, 21st of December, 4 pm, CIE clear sky sun



4) Results of the three possible positions for the 21st of June, 9 am (figure 6a & 6b):
The position –30° causes glare at 3 m and is being excluded from this analysis. The position 0° improves the daylighting at 1.0 m around 27%, at 3.0 m around 30%, at 5.0 m around 50%, at 7.0 m around 80%, at 9 m around 25%.

Figure 6a: Results of Full Range, 21st of June, 9 am, CIE clear sky sun

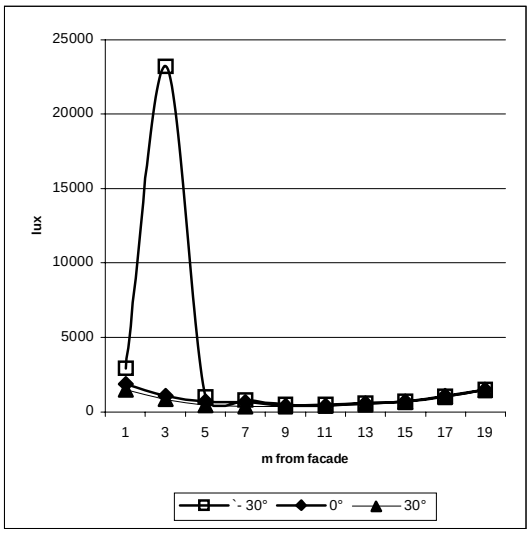
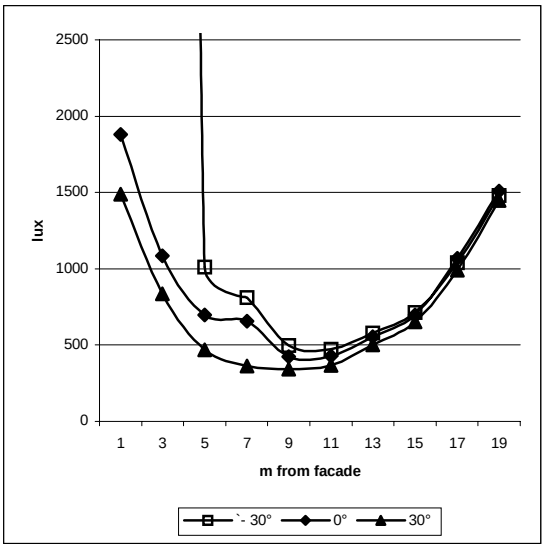
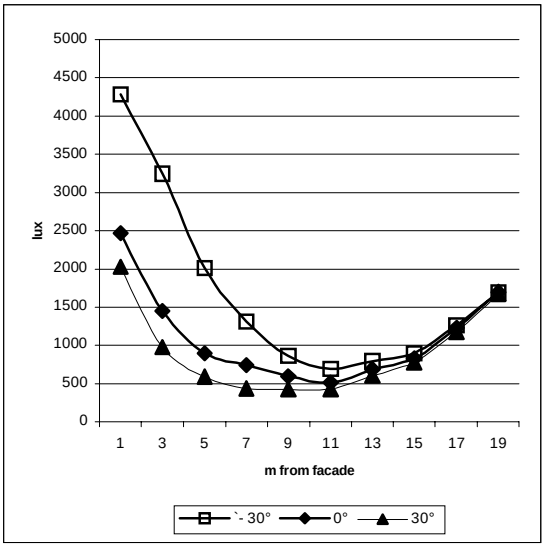


Figure 6b: Results of Comfort Level, 21st of June, 9 am, CIE clear sky sun



5) Results of the three possible positions for the 21st of June, 12 am (figure 7):
The position –30° rises significantly the daylighting level. It still does not cause glare or thermal discomfort and might be helpful when partitions are used. The position 0° improves the daylighting at 1.0 m around 27%, at 3.0 m around 50%, at 5.0 m around 52%, at 7.0 m around 72%, at 9 m around 41%.

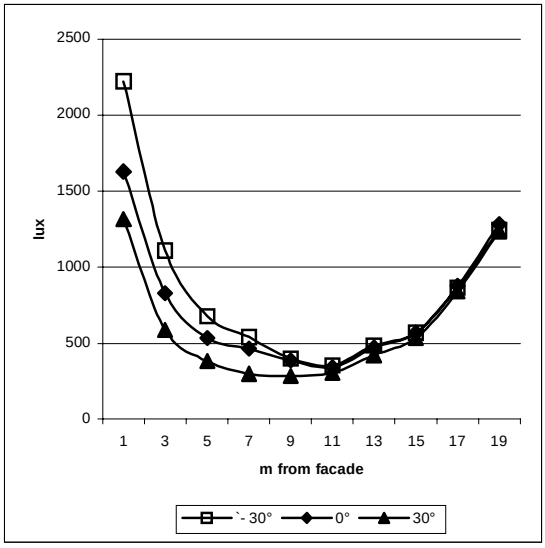
Figure 7: Results of Full Range/Comfort Level, 21st of June, 12 am, CIE clear sky sun



6) Results of the three possible positions for the 21st of June, 4 pm (figure 8):
The position –30° rises significantly the daylighting level, so at 1.0 m around 69%, at 3.0 m around 88%, at 5.0 m around 77%, at 7 m around 82% and at 9 m around 40%. It still does not cause glare or thermal discomfort and might

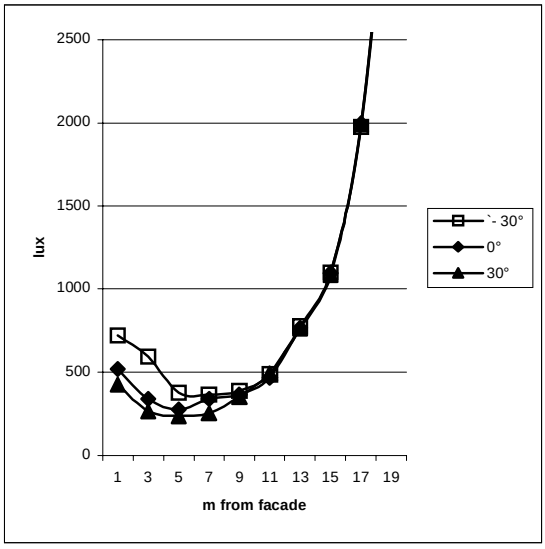
be helpful when partitions are used. The position 0° improves the daylighting between 1.0 m and 9.0 m in average around 40%.

Figure 8: Results of Full Range/Comfort Level, 21st of June, 4 pm, CIE clear sky sun



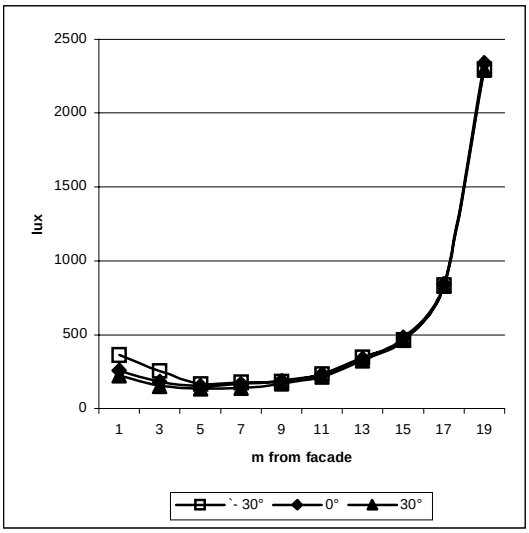
7) Results of the three possible positions for the 21st of December, 9 am, CIE intermediate sky and sun (figure 9):
The position –30° rises significantly the daylighting level, so at 1.0 m around 69%, at 3.0 m around 124%, at 5.0 m around 60%, at 7 m around 44% and at 9 m around 10%. The position 0° improves the daylighting between 1.0 m and 9.0 m around 10 - 15%.

Figure 9: Results of Full Range/Comfort Level, 21st of December, 9 am, CIE intermediate sky sun



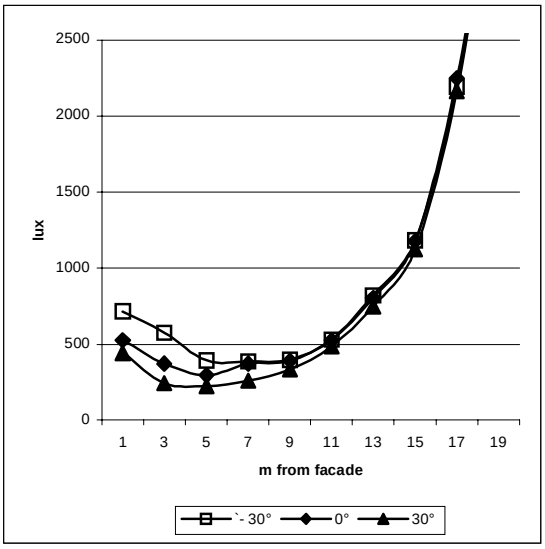
8) Results of the three possible positions for the 21st of December, 12 am, CIE intermediate sky and sun (figure 10):
The improvements by the two alternative positions are not significant.

Figure 10: Results of Full Range/Comfort Level, 21st of December, 12 am, CIE intermediate sky sun



9) Results of the three possible positions for the 21st of December, 4 pm, CIE intermediate sky and sun (figure 11):
The position –30° rises the daylighting level at 1.0 m around 62%, at 3.0 m around 140%, at 5.0 m around 75%, at 7 m around 49% and at 9 m around 19%. The position 0° improves the daylighting at 1.0 m around 19%, at 3.0m around 55%, at 5.0m around 32%, at 7.0m around 44% and at 9.0 m around 17%.

Figure 11: Results of Full Range/Comfort Level, 21st of December, 4 pm, CIE intermediate sky sun



10) Results of the three possible positions for the 21st of June, 9 am, CIE intermediate sky and sun (figure 12a & 12b):

The position –30° allows direct solar radiation, causing glare and thermal discomfort and is considered any more for this situation.

The position 0° improves the daylighting at 1.0 m around 19%, at 3.0m around 58%, at 5.0m around 38%, at 7.0m around 68% and at 9.0 m around 31%.

Figure 12a: Results of Full Range, 21st of June, 9 am, CIE intermediate sky sun

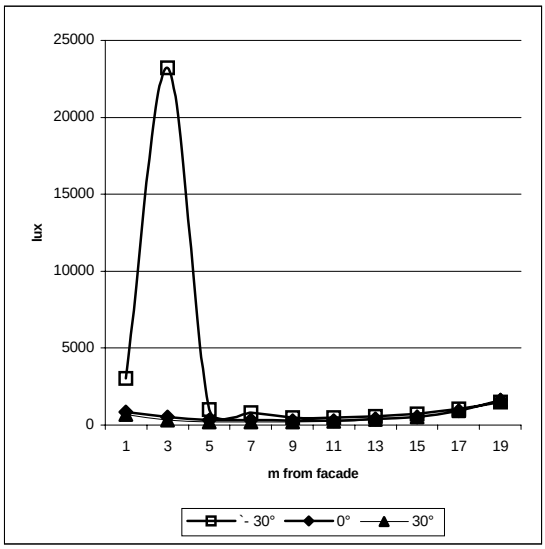
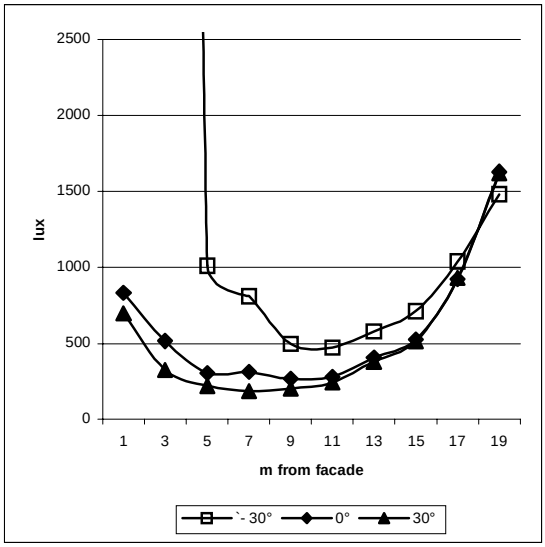


Figure 12b: Results of Comfort Level, 21st of June, 9 am, CIE intermediate sky sun

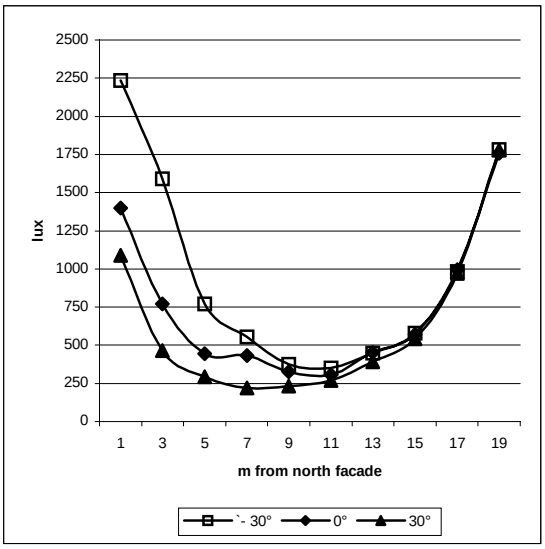


11) Results of the three possible positions for the 21st of June, 12 am, CIE intermediate sky and sun (figure 13):

The position –30° improves quite significantly the daylight offer in the office space: at 1.0 m around 106%, at 3.0m around 242%, at 5.0m around 161%, at 7.0m around 253% and at 9.0 m around 63%.

The position 0° improves the daylighting at 1.0 m around 29%, at 3.0m around 65%, at 5.0m around 51%, at 7.0m around 96% and at 9.0 m around 41%.

Figure 13: Results of Full Range/Comfort Level, 21st of June, 12 am, CIE intermediate sky sun



12) Results of the three possible positions for the 21st of June, 4 pm, CIE intermediate sky and sun (figure 14):

The position –30° improves quite significantly the daylight offer in the office space: at 1.0 m around 69%, at 3.0m around 88%, at 5.0m around 77%, at 7.0m around 82% and at 9.0 m around 40%.

The position 0° effects generally lower values than position 30°.

Figure 14: Results of Full Range/Comfort Level, 21st of June, 4 pm, CIE intermediate sky sun

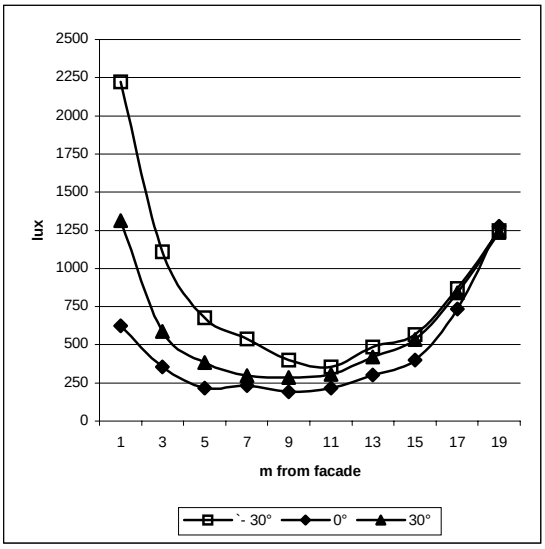
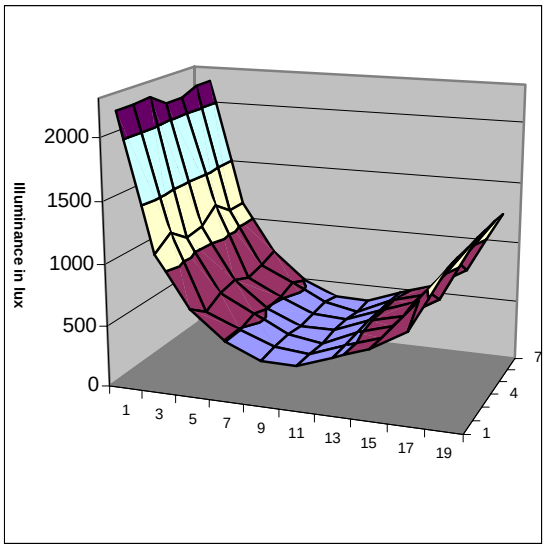


Figure 15: Daylight distribution, CIE intermediate sky with sun, 4 pm, position –30°



The 3D – daylight distribution is pretty similar in all simulated cases. The isolux – curves run almost parallel to the south and north facades (example figure 15).

ANALYSIS:

The daylighting offer in the office space was evaluated with Radiance for two different days at three different times of the day and two different sky conditions for each day respectively each time. That makes total of 12 different sky conditions for the simulations.

Three different positions of the horizontal brise soleil were checked. That makes a total of 36 different combinations.

In four combinations direct solar radiation would cause glare and thermal discomfort (figure 6a/b (-30°), 12a/b (-30°)). Two of the four combinations were found through visual control with rpict (corresponding to fig. 7 (-30°) and fig. 14 (-30°). In both cases the penetration is limited to a small area close to the façade (see fig. 16 & 17).

Figure 16: Daylight distribution, Cie clear sky sun, 9 am, position –30°

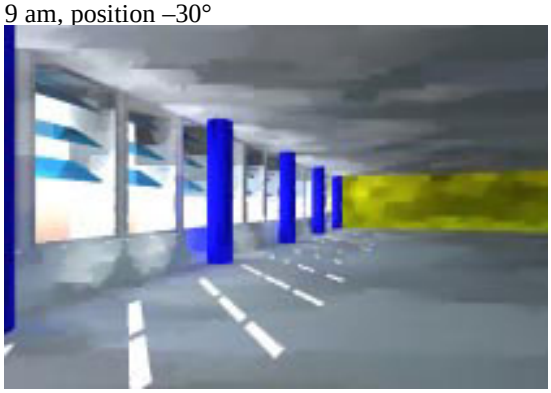
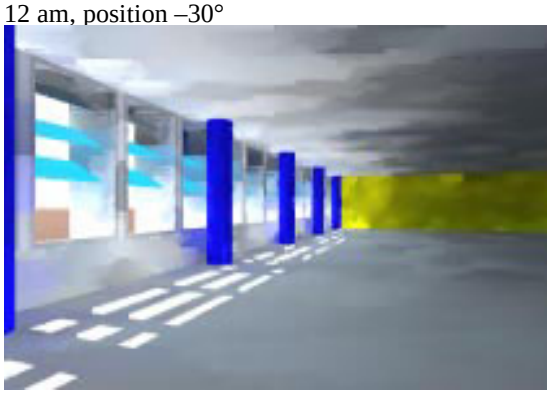


Figure 17: Daylight distribution, Cie clear sky sun, 12 am, position –30°



In seven combinations, (fig. 3 (0°), fig. 5 (0°), fig. 9 (0°)fig. 10 (-30°, 0°), fig. 11 (0°), fig. 12a/b(0°), the improvements are not significant.

In 13 combinations the daylighting is improved considerably, compared to the standard position at 30°: (fig. 3 (-30°), fig. 4 (-30°/0°), fig. 5 (-30°), fig. 6 (0°), fig. 7 (-30°/0°) – the -30° position represents direct radiation, detected by visual control (fig.17), fig. 8 (-30°/0°), fig. 9(-30°), fig. 11 (-30°), fig. 13 (-30°/0°), fig. 14 (-30°/0°). the –30° position represents direct radiation, detected by visual control (similar to fig. 17)

CONCLUSION:

There are 2 times 3 combinations at the same day and time, reducing the real possibilities to improve the daylight situation to 10 occasions in 12 possible ones. That means, that in 83% of the occasions (2 different days, 3 different times of the day, 2 different sky conditions) artificial lighting could be avoided by changing the position of the horizontal blinds.

This evaluations proves clearly, that the design considerations of the architects, led by Lúcio Costa more than 60 years ago, were absolutely correct.

That the devices are not used in the right way is a problem which is confronting architects and engineers all over the world until today: the building users active participation in the adaptation of the building devices to changing climatic parameters is almost impossible to achieve. It already does not work well in family homes, where time is more abundant and the responsibility is quite clear. Therefore nobody can expect to get it done in an office space, where the focus is on the job to be done and not on the correct position of the blinds.

The solution might be found in automatic systems. A retrofit of the MEC would be technically possible, as the existing mechanism is quite balanced and works fine.

This paper shows clearly the advantage of Radiance as a simulation tool for existing buildings: Radiance in most cases is used to check situations in the planning stage, when real measurements are impossible because of the non-existence of the physical space. In the case of the MEC real measurements are possible and were actually planned. But due to the huge amount of time and equipment necessary to carry out this research Radiance came into play – and proved to be perfect for the job.

REFERENCES:

[1] Mindlin, Henrique [1999] Arquitetura moderna no Brasil. Aeroplano Editora. Rio de Janeiro/Brazil, p. 218

[2] Ward, G. [1994] The RADIANCE 2.4 Sysnthetic Imaging System, University of California, Berkley, USA

[3] Laar, Michael [2001] Daylighting in the Tropics – an Evaluation of Sky Luminance, Glare Perception and Veiling Reflections on VDTs in the Tropics. 18th International Conference PLEA, Florianopolis 2001 (full paper accepted)

[4] Corbella, Oscar [1995] Reconstrução e análise de dados de radiação solar e horas de brilho solar para a cidade de Rio de Janeiro. Anais do III Encontro Nacional/I Encontro Latino-Americano de Conforto no Ambiente Construído. Gramado/Brazil, p. 170

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