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NUMERICAL EVALUATION OF THERMAL PERFORMANCE IN MARIANA CITY HALL BUILDING

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Abstract. According to the great amount of raw material and incentives generated by companies in metallurgic sector in building construction, in Minas Gerais State steel structured buildings are gaining space. Some steel structured buildings with local relevance in Mariana emerged in the eighties, among those was the City Hall building. In this paper Mariana's City Hall building thermal performance is evaluated, which is structured in steel construction, presenting thermal comfort problems for its users particularly in summer days, due to high internal temperatures. The software *EnergyPlus* is used to perform the simulations with emphasis on thermal analysis, considering natural ventilation. Some architectural strategies are proposed to improve the building's thermal performance. These strategies provide a direct solar radiation reduction which occurs inside these environments and correspond to the polycarbonate roof replacement which exists in ceramic tiles and/or insulated roof sandwich panel and the placement of facades brises. With the obtained results it is inferred that the strategies provide an improvement of building's thermal performance around 25 to 35% according to the modern architectural setting.

1 INTRODUCTION

In Brazil, the use of steel in Architecture and Building Construction has been increased over the years. Until the seventies, the metal buildings were restricted mainly to industrial facilities in the sheds configuration. Only since the mid-eighties, it became common to use the metal structure on a larger scale. Currently, it is experiencing an expansion of new constructive technologies according to the market's rules, because increasingly there is a search for alternative systems to increase productivity, reduce the constructive period and eliminate the waste, and among them there is the steel structured construction (Moraes, 2000).

Today, much of the steel construction in Brazil is present in large constructions and many of them are high standard undertakings, where the implementation deadline is essential, justifying the structural system's choice and the construction cost. Usually these buildings are intended for institutional use, such as public buildings (city halls, forums, town halls), buildings for commercial purposes as hotels, banks, airports and supermarkets, and buildings for health and education purposes.

The adoption of the industrialized constructive process, such as steel, requires the technology's knowledge, and the lack of this knowledge may involve the incompatible systems selection generating future pathologies and problems in the building's thermal performance. So after the structure's choice, it is necessary to make a study about the outside walls types, covers among other outside walls elements, evaluating their thermo-acoustic properties, as well as its feasibility with the structure and the construction's cost.

This research is a thermal performance evaluation of Mariana City Hall main building, which is a steel structured construction, and presents thermal comfort problems to its users. After a study of post-occupancy evaluation made in this building (Rocha, 2007), it was realized that the building presents high internal temperatures mainly in summer days. Architectural strategies have been proposed in order to minimize the internal temperature, as well as the replacement of the polycarbonate roof for insulated roof sandwich panel and also the solar protection placement in facades.

2 COVERING ROOFS AND SOLAR PROTECTION

2.1 Covering with insulated roof sandwich panel

The building's covering system is intended to close the construction, protecting its interior from the weather. During the coverage's design phase, it is important to be careful in the roof's shape developing and choose the material type which sets the tiles. According to Hertz (1998), the roof is the most exposed area to the sun, and it is during the day that there is a large internal energy variation in this part of the building, being necessary to prevent the heat to reaches the construction's interior.

Relating to the material which sets the tiles, it is necessary to choose a material with low thermal transmission, with thermo-acoustic properties or with reflecting film to minimize the heat increases inside the building. In the market there are common metal tiles available which, besides having high thermal transmittance, cause much noise and the insulated roof sandwich panel are more efficient, in which both external sides are made of zinc steel pre-painted in bright colors or in aluminum and the core can be made in EPS (expanded polystyrene), in PUR (polyurethane foam), in PIR (poliisocianurate) or in LDR (rock wool). Today, the insulated roof sandwich panel are widely used, due to their low acoustic transmission as well as being an outside wall material accessible to large and small constructions.

2.2 Solar Protections

The use of solar protections can reduce the solar radiation impact inside the building, contributing to better light distribution inside the rooms. According to Olgyay and Olgyay[1] (1963) apud Loura (2006) the satisfactory solar protection performance is influenced mainly by three factors, which are: the used material reflectivity and its color; the protection element's location, because if it is wrong positioned can allows radiation and heat convection into the building, and the efficiency of the chosen protection method.

Several strategies can be obtained for the development of an effective solar protection. The ideal is that in the project's development phase the construction's direction and the openings positioning had already been studied. According to Silva (2007), the use of an external and internal solar protection element as a balcony, covered terrace, vertical brise-soleil, horizontal brise-soleil, brise-soleil composed of vertical and horizontal plates (mixed), special screens, awnings, curtains and persian blinds, drained elements, pergola, reflective glass and vegetation, can be used as strategy for getting good lighting and ventilation without excessive heat. The choice of the most suitable device for the location (vertical, horizontal, mixed, fixed or mobile) should consider its solar orientation as well as issues such as visibility, light and costs.

3 CONTRUCTION'S THERMAL PERFORMANCE EVALUATION

3.1 Construction Thermal Simulation

The use of thermal and energy simulation in buildings has been widely used by architects and engineers, as a tool to sizing the air conditioning systems, retrofit studies and heat transfer calculation through constructive systems and by the soil, allowing the evaluation of many materials available in the building industry in various localities where there are weather data available (Batista; Lamberts and Westphal,

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[4] OLGYAY, V. and OLGYAY, A., *Design with climates: bioclimatic approach to architectural regionalism*. Princeton: 1963. 190p, 1963.

2005).

In this study it is used the EnergyPlus software with thermal analysis emphasis. A typical summer day is considered, since the post-occupancy researches showed that this building presented more discomfort to its users during the summer. Weather data was used from Belo Horizonte city because of the difficulty to obtain weather data from Mariana city. The typical summer day considered for Belo Horizonte city was February 02 and was obtained by the methodology presented by Akutsu (1998) considering 10 years of data interval. The thermal performance evaluation accomplishment in a naturally ventilated building through numerical simulation should follow the steps showed in the flow chart presented in figure 1.

As an evaluation rule for human comfort, it was adopted the ASHRAE 55 Standard (2004), considering the comfort temperature range between 19ºC and 28ºC. In this research was considered the upper limit (summer conditions) to the results evaluation.

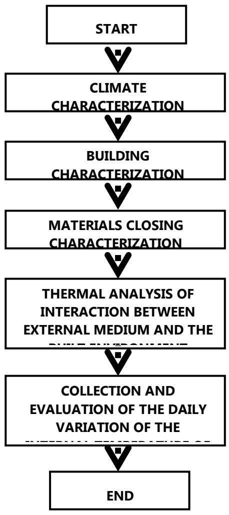

Figure 1: Key elements flow chart for numerical simulation of a naturally ventilated building. Source: AKUTSU, 1998.

3.2 Construction Case Study: Mariana City Hall's Main Building

The building has two floors, in which are located the receptions rooms and offices. The first floor's height is 3.15 m and the second floor is 3.30 m. The internal and external covers are made of masonry, with ceramic brick of 15 cm of thickness. The walls are lined on both sides with 2 cm of mortar, painted with latex paint, having the external faces painted in light blue and the internal faces painted in light yellow. The openings are made in light profiles, known as metalon, painted in white, filled with simple glass. The openings are usually sliding windows and some access doors to the building. The internal doors are made in plywood-type clipboard. The building's floor is granilite in gray, and the lining is made with the PVC material in white. The first floor slab is pre-shaped and on the second floor there is no slab (Figure 2).

(a) (b) (c)

Figure 2: Photos of the: (a) front facade; (b) central corridor; (c) inside the room (area) 23.

The coverage is made of ceramic tiles in most of the building. In the corridors and reception in the second floor, the coverage is made of transparent polycarbonate. There is an edge around the building, and this is the only protection for the openings. Due to the high solar radiation incidence through the polycarbonate coverage, were installed some canvas lined in aluminum below this coverage, to minimize the heat entrance in the internal place.

For the simulation of the studied object, the temperature zones were limited to the workplace (several rooms belong to the same workplace, separated by dividing with lower height) totaling 33 areas, in addition to the areas formed by the attic belonging to the coverage. The thermal zone presented in this research refers to the area 23, which is located on the second floor of the building with solar orientation facing the northeast region (Figure 3).

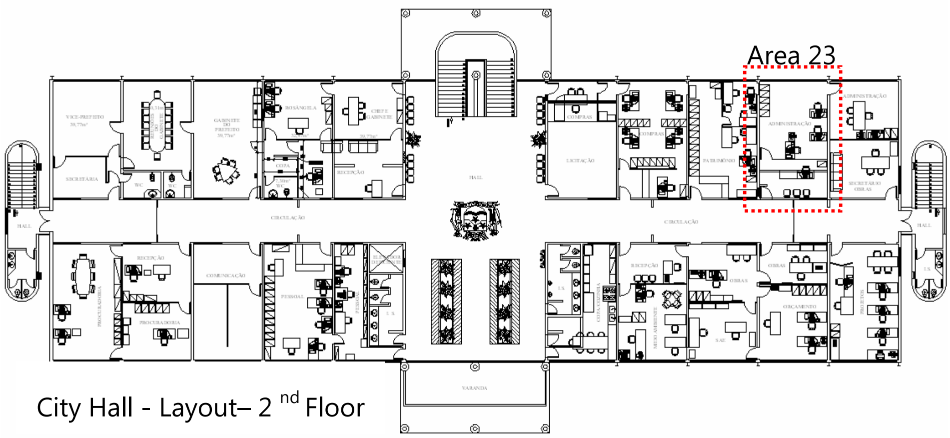

Figure 3: Second floor's low plant.

The building's occupation routine studied was the working routine time of the City Hall, which is from 8 am to 6 pm. As internal heat gains were considered the equipment (computers), fluorescent lighting and the occupants (employers) in each room.

4 RESULTS

The presented results show the internal temperature and the parameter hours/degrees, representing the resulting temperature difference with the maximum temperature set for the comfort range of 28ºC, according the ASHRAE 55 Standard (2004).

4.1 Solar Protection Implementation in the Facades - Strategy 1

It is proposed the solar protection placement in the facades in order to minimize the solar radiation incidence inside the building - strategy 1- (Figure 4). Studies were made with the shadow mask to the east and west facades, which are critical facades of solar incidence, considering the months and warmer times of the year. Through the shadow mask was chosen the 30º angle, with vertical shading device, both for the east and west facade, because it was the best situation for the total and partial shading in the critical months and times (the summer months with times from 4 pm to the west facade and from 8 am for the east facade). Figures 5 and 6 presents the internal temperature and the hours.degrees required for local cooling.

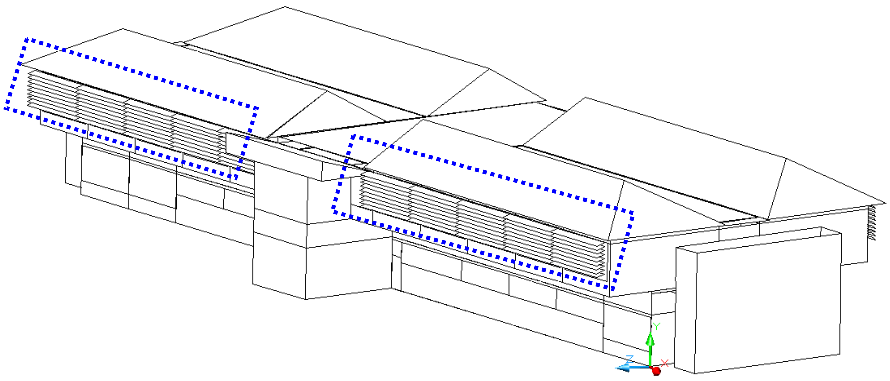

Figure 4: Solar protection in the east and west facades.

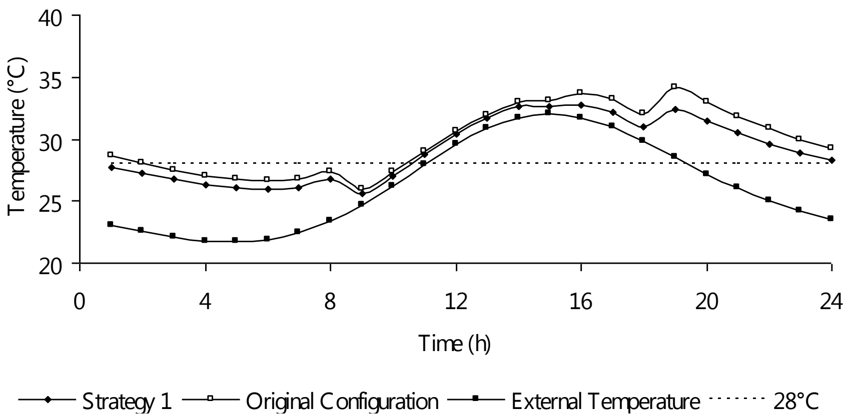

Figure 5: Internal temperatures (area 23) and external.

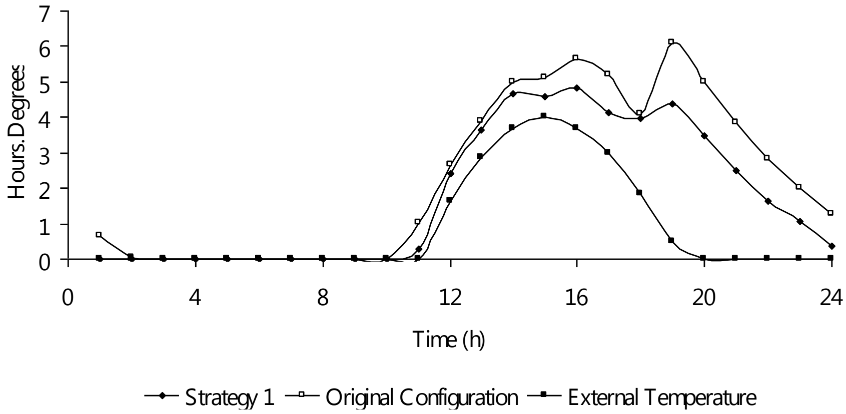

Figure 6: Hours.degrees needed for local cooling (area 23).

It can be inferred (Figure 5) that the solar protection presence reduced the internal temperature, reducing temperature at 16pm (time of the highest temperature of the occupation period) in 1.0 ºC. In the results obtained in Figures 5 and 6 a satisfactory performance of the strategy 1 is observed reducing the hours.degrees, necessary for the local cooling, an average of 4.0 ºC per hour, during the building occupation (occupants working time). Comparing the strategy 1 with the original setting, the hours.degrees reduction was around 25 %.

4.2 Replacing the polycarbonate coverage by insulated roof sandwich panel – Strategy 2

It is proposed by the strategy 2, the replacement of the polycarbonate coverage by metal tiles with thermo-acoustic insulation filled with polyurethane, aiming to reduce the solar radiation incidence inside the building (Figure 2 – b). Figures 7 and 8 presents the internal temperature evolution and the hours.degrees required for local cooling.

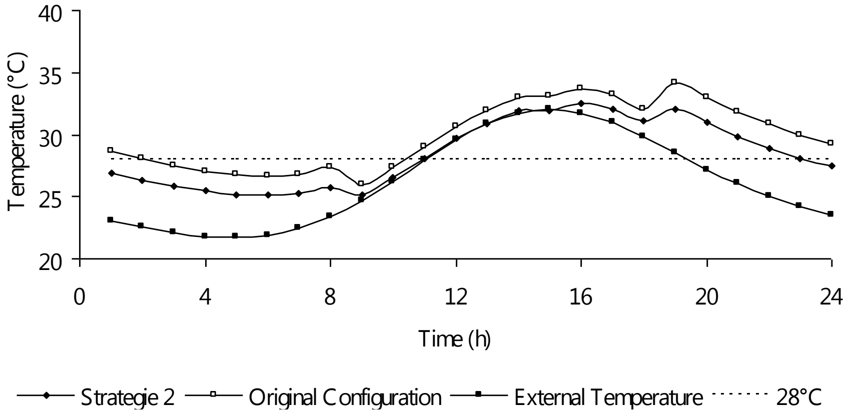

Figure 7: Internal temperatures (area 23) and external.

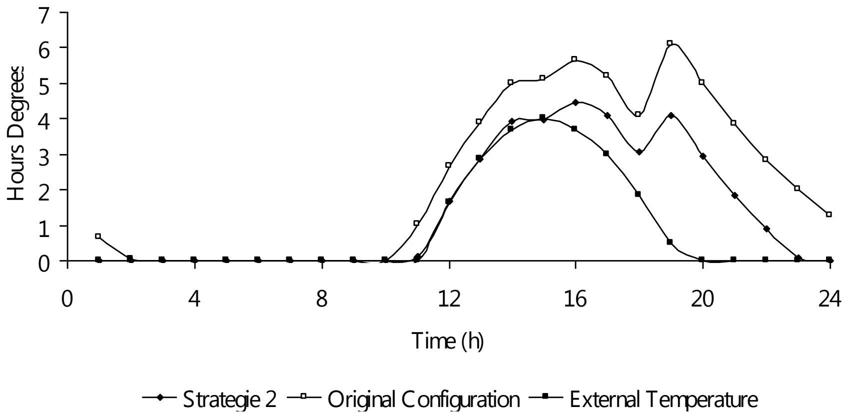

Figure 8: Hours.degrees required for local cooling (area 23).

It can be observed (Figure 7), that the insulating tiles use on the central corridor, helped to reduce the air internal temperature, with approximate reduction values in the period where the windows were always open, from 8 am to 6 pm, whose value was on average 1.1ºC, and during the working time when the internal temperature is higher, the reduction was on average 1.5 ºC. It is shown in Figure 8 results, that there was a drop in the hours.degrees values when there is replacement of the polycarbonate coverage by insulating tiles. The reduction between strategy 2 and the original configuration was 1.8 ºC per hours, meaning that there was a reduction around 31 % of the hours.degrees required for local cooling.

5 CONCLUSION

It can be concluded that these architectural strategies, as placing solar protection in the east and west facades (strategy 1) and the replacement of the polycarbonate coverage by insulating tiles (strategy 2), which interfere in reducing the direct solar radiation, presents a good thermal performance resulting in a lower hours.degrees amount required for local cooling (area 23). The reduction of the polycarbonate area coverage and the shading of the east and west facades in periods of high temperature contributed to an average reduction of 28 % of hours.degrees compared to the original setting. The use of metal insulating tiles showed better results compared to the use of solar protection in facades, with a reduction of 31 % of hours.degrees. Furthermore, this strategy implementation is not expensive, because it is easy to apply in the place and minimizes the fans and air conditioners use.

Acknowledgements

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