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Building Energy Modelling in Bogota City

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Abstract

The drive for developing more energy efficient buildings is spreading around the world. In tropical countries, such as Colombia, the main drivers of energy consumption are usually illumination and, lately, cooling systems, which are being implemented more frequently due to climate change. Three typical buildings in Bogota were chosen for energy performance analysis using Dynamic Thermal Simulations. The results showed that the premises tend to be illuminated inefficiently and the energy consumption can be significantly improved by taking advantage of daylight. Some designs lend themselves to implementing more effective natural ventilation strategies that can improve indoor thermal comfort and reduce the need for, or the extensive use of, air conditioned systems.

Keywords: energy performance; daylight; hybrid systems

1. INTRODUCTION

The development of the city has converted Bogota into a metropolitan centre of the country and an important venue of Latin-America. Therefore, its future is looking forward to greater organization and modernization through an integral process, where efficient and sustainable buildings play a very important role. Due to its location, the city presents temperatures of maximum 25°C and a daily average of 15°C (IDEAM, 2004); conditions that avoid the need of space heating in commercial buildings. Consequently, the major energy consumptions are usually associated with illumination, and occasionally with mechanical ventilation systems. This paper reports on dynamic thermal simulations that were carried out to investigate the performance of typical buildings in the city of Bogota.

2. METHODOLOGY

Three representative buildings of Bogota, Colombia were chosen for energy performance analysis. Models of the buildings were created with the Software IES-VE© (IES, 2011) to undertake Dynamic Thermal Simulations (DTS). The climate data was obtained through the generator: *CCWeatherGen* (U. of Southampton, 2010), converted to an EPW file and compared with data from IDEAM to guarantee its accuracy. The models were created based on architectonical or structural plans and further input data such as mechanical systems and internal heat gains were estimated based on records of visits made to the buildings in use. The chosen buildings are briefly described as follows:

2.1 Shopping Centre

The "*Paseo San Rafael*" (PSR) Shopping Centre, is located in the north of the city, was opened in 2004 and services a population of around 350,000 people. It comprises 73 spaces between stores, restaurants, cinemas and services in a useful area of approximately 20,000m², distributed over four floors. The centre is open daily from 8:00 to 24:00. Figure 1 shows a photograph of centre and Figure 2 shows its representation.

Figure 1: Photograph of "Paseo San Rafael" Shopping Centre (Bogota.vive.in, 2011)

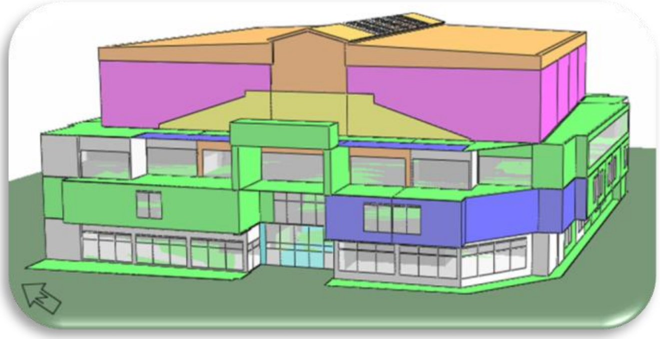

Figure 2: Representation of "Paseo San Rafael" Shopping Centre for Building's simulations

2.2 Health Centre

The "*CAFAM Floresta*" Health Centre is a 5-storey building located in the north of the city, with an approximate floor area of 7,672m², forming part of a commercial complex of more than 70,000m². It was constructed in September 2006 to support the *CAFAM Health Care Promoting Entity*. It receives 24/7 emergencies, but is not equipped to perform major surgical procedures.

There are 97 practice rooms, including rooms for specialized procedures and X-rays. In addition, the building contains offices, conference rooms, a supermarket, a café, a library, one IT room, and an entertainment zone. The practice room and the general services are open from 6:00 to 17:00 from Monday to Saturday. Figure 3 shows a photograph of the Health Centre and the Figure 4 shows its representation.

Figure 3: Photograph of "CAFAM Floresta" Health Centre. 2007

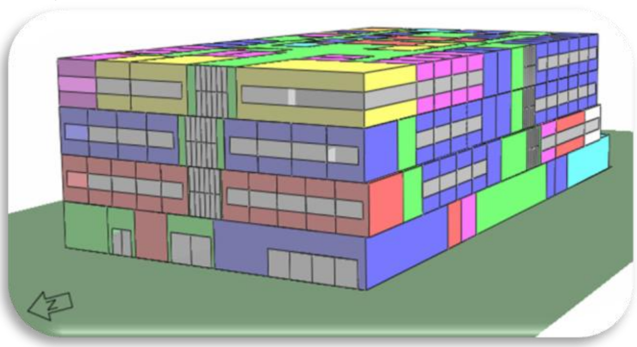

Figure 4: Representation of "CAFAM Floresta" Health Centre for Building's simulation

2.3 University Building

This Building is located in the north zone and forms part of a private Health Foundation, with several buildings including a clinic, practice rooms, emergency unit and other student's facilities such as seminar rooms, library, etc. Since the Building is connected with these other facilities, it is mainly provided with classrooms, laboratories, a library and offices. The Building started operating on 2005 and it has in total 5,103m². The building is open in general from 7:00 to 18:00 from Monday to Saturday. The Figure 5 shows the model representing the Building.

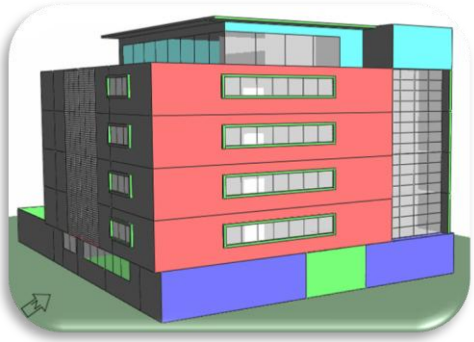

Figure 5: Model of University's Building for simulation

3. RESULTS AND ANALYSIS

3.1 Shopping Centre

The simulation for the base-case scenario estimated that the complete building consumes in total 8,334.07 MWh a year, which is equivalent to 382,70 kWh/m²/year. Approximately 70% of this total consumption is used in electricity.

A comparison of the simulation results was made with figures of benchmarks from the city, reported in the *Characterization of Energy Consumption* (UPME, 2007), segregating the general consumption of shopping centres and the most common spaces within them. The comparison showed that the energy consumption in illumination is lower in all the spaces of the PSR Shopping Centre against the benchmarks, although there are premises with power consumption up to 21 W/m², as it is the case of the supermarkets, and no sensors are used in any space. However, the PSR Shopping Centre presents a higher expenditure in air conditioning systems, even though they are only used in the cinemas and two specific rooms: a Casino and a Games Room.

3.2 Health Centre

The simulation showed that the whole building can consume 319.44 kWh/m² of energy during a year; where approximately 65% of it is due to hot water used mostly for cleaning and catering. In electricity, the building consumes 110.94 kWh/m², with a monthly average of 9.24 kWh/m².

Benchmarks show that for hospitals, more than half of the total energy is consumed in natural gas due to their high demands of loads for cooking and cleaning, while the health centres usually do not provide this kind of services. The "*CAFAM Floresta*" Health Centre however, is a mixture between the two services, and present figures of energy consumption in natural gas and electricity for illumination between the figures of the two groups. Nevertheless, regarding other electricity uses, the case study can consume around 25% more than hospitals and 70% more than other health centres.

3.3 ***University Building***

The base-case scenario estimated that the Building can reach a total annual energy consumption of 392 MWh, with a monthly average of 7.3 kWh/m² in electricity, which is the major consumption.

The comparison with benchmarks showed that the illumination of the case study has a consumption of 32% above the benchmarks for universities. In addition, the universities in Bogota do not usually use AC systems; however, this Building does, due to its proximity to a noisy and polluted avenue.

4. DESIGN ALTERNATIVES

4.1 Shopping Centre

4.1.1 Artificial lights linked to illuminance levels

The PSR Shopping Centre is provided with roof lights at the central atrium and glazing at the front and back facades, allowing good natural light into the building. A Radiance© simulation (IES, 2011) was performed activating sensors in the model and a step function was implemented to turn on the artificial lights when the illumination levels lay below 300Lux in corridors and the food court, and below 500Lux in the offices and the banks.

According to the architect, although some stores are also provided with glazing, the area adjacent to this glazing is often used as storage. The reason for this being that uncontrolled natural lighting can seriously damaged products such as clothing, shoes or fabrics, by altering the colours, or perishables, by altering their properties and composition. Consequently, no light sensors in stores or supermarkets were evaluated in the simulations.

The results shown that, by implementing the strategy in the three groups, the total lighting consumption can be reduced from 999.25 MWh to 968.35 MWh, which represents 3% savings in the electricity for artificial lighting. But, looking deeper into the savings by group, it can be seen that implementing photosensors in the banks reduce artificial lights in 38%. This is likely to be due to the fact that they tend to be more highly illuminated than other spaces; with 15 W/m².

4.1.2 Reducing AC loads

Since the cinemas would require a complex design to reduce the AC loads without disturbing the sound insulation and the acoustics of the spaces, the measures implemented in this study only involved the Casino and the Games Room.

A hybrid system was considered. For this purpose, small openings were put into operation below the existing glazing representing approximately 10% of its area, and additionally, openings in a free area of the ceiling of the same dimensions were also implemented, to allow stale air to leave the room by buoyancy effect. The results of this simulation showed that by using natural ventilation, AC loads can be reduced more than 60% in these spaces leading to nearly 6% reduction in the total energy consumption for the whole building.

4.2 Health Centre

4.2.1 Implementation of photosensors

Photosensors were implemented to turn off the artificial lights when the natural lighting levels are sufficient to illuminate the space depending on their specific requirements. The results of these simulations by groups showed that spaces such as offices and general practice rooms can save more than 20% of the energy they consume for artificial lights, and a reduction of 12% in the total energy consumption could be achieved.

4.2.2 Natural Ventilation

The simulations showed that by opening the windows in the practice rooms 10% of the available glazing area (approx. 2.6m²/room), enables airflow of more than 30 l/s into the room, which is sufficient for occupancy of 2 to 3 people per room. If controls were installed in these windows to modulate the airflow according to the internal and external conditions, mechanical ventilation would be unnecessary. If this measure were implemented in the practice rooms of the top three storeys provided with windows, where noise is not high, the mechanical ventilation could be reduced by 14%.

4.3 University Building

4.3.1 Implementation of photosensors

Following a similar procedure as in the previous cases to allocate photosensors, simulations showed that the energy for lighting can be reduced from 197.98 MWh per year to 180.25 MWh, which represents a reduction of nearly 9%.

4.3.2 Evaluation of a hybrid system

The design process for the implementation of a hybrid system is briefly described as follows: first, it was verified that sufficient flow can be obtained through the existing openings. Then, the classrooms were provided with openings, at the top of the back wall in order to change the single-side ventilation into a cross ventilation. In addition, since these classrooms are directly connected to a central corridor, a central opening was enabled in order to promote the buoyancy effect. Finally, further openings were added at the highest levels of the last corridor to enable the outflow.

The simulation successfully showed that the strategy allows energy savings of 45% in the energy of the system and of almost 20% in the total energy consumption.

5. DISCUSSION

This study focused in analysing the possibilities of saving energy consumption in the two main services whose behaviour is directly influenced by the building design, according to the requirements that the city's characteristics impose: artificial lighting and mechanical ventilation.

It was shown that even with low figures of energy consumption in lighting, in comparison with the benchmarks, it is possible to reduce considerably this consumption by taking advantage of the natural light and implementing sensors that modulate the artificial lights according to the natural illuminance and the recommended levels for the activities that take place in the zone. Loads in the mechanical systems, can also be significantly reduced by improvements in the building design, together with an automation of the strategy's controls to guarantee the suitable tuning to provide enough airflow avoiding discomfort due to draughts or rain.

Figure 6 summarized the savings due to the measures implemented in specific spaces against the maximum possible in the building. The savings by spaces can be great and they can represent significant savings in the total energy consumption of the building, but this depends on the extension of the areas where they can by applied. Taking the Shopping Centre as an example, the photosensors in the Banks could reduce the use of artificial lights in nearly 40%, but in total, the savings could only reach 3%, since is not possible to use them in all the premises. A similar situation is observed by implementing a hybrid system, which could be only used in two rooms; where the savings exceed the 60%, but in total, this only represents approximately 5%, since it cannot be applied in the cinemas, where the use of the AC is the highest.

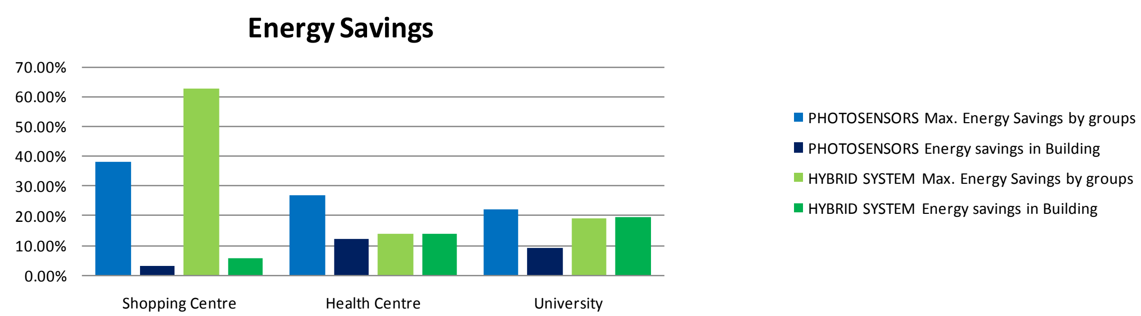

Figure 6: Energy savings due to Photosensors and Hybrid systems. Comparison of maximal local savings against reductions in the total energy consumption of the building.

6. CONCLUSION

The analysed buildings have a good potential for energy savings by taking advantage of natural light since they tend to have extensive glazing but not use of photosensors. In addition, design improvements that promote natural ventilation forces, can produce significant reductions in the loads in mechanical ventilation systems.

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