Strategies of natural ventilation for hospitals: a comparative study between hospitals in the city of Rio de Janeiro and the Brazilian standard of thermal performance

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Abstract. With the introduction of technological advancements in buildings and specially in health environments, such places became even more enclosed and automatized. The choice for the proper air ventilation system must be careful, for that is the biggest energy consumer in hospitals and decisive for inner air quality. This article has the objective to analyze natural ventilation strategies and thermal development in two wards located in two hospitals in the city of Rio de Janeiro - Brazil, computer modeled and simulated. The discussion raises the following questions: 1. Do the ward windows at both hospitals meet the requirements for environmental comfort? 2. If so, for which months? Through bibliographical review building analysis were made, an architectural survey and computer simulation were made using DesignBuilder, taking into consideration all months of the year for the comfort and discomfort sensation frequencies. The results obtained point to a desired thermal comfort in both case studies throughout the months of April to December according to the span for acceptable operative temperatures in naturally ventilated buildings defined by ASHRAE 55-2013.

1. Introduction

Since the middle of the last century, there has been an increase of ventilation systems inside buildings. The concentration levels indoor the building can be 2 up to 5 times higher than outdoor levels [1]. Physical factors, such as temperature, humidity, air circulation and renewal not only affect the development of microorganisms in indoor environments, but also the dispersion and dilution way of contaminants. According to Verderber (2010), natural ventilation must be utilized in a careful way inside hospital facilities [2]. In the specific case of Health Units, air quality may have a direct and significant influence over patient recovery speed and infection occurrences. It is necessary to observe that not all environments may benefit from natural ventilation, for these need a rigorous control over airborne particles in order to avoid contamination.

As for internal air movement, good ventilation depends on the pressure on the four sides of the building, which may be achieved by the correct opening placement, hence the geometry of the building is an essential factor [3]. Buildings with openings towards external areas facilitate natural ventilation occurrence. The integration between internal and external environments are constructive characteristics that favor air flow, as well as the use of balconies, pergolas, hollow elements, skylights, zenith-angled openings, among other strategies that allow air permeability whilst protecting and filtering natural luminosity [4].

In the case of hospitals, ventilation is decisive for air renewal and assepsis maintenance of indoor environments, since closed spaces may favor bacteria and disease spread. Adequate humidity rate is between 40% and 60% [4]. Favorable conditions for microorganism spread occur with humidity rate ranging from 70% to 80% and temperature of 25 ºC. There are available options for the control of
infectious agents transmitted through the air such as ventilation, air renovation, filtering, ultraviolet radiation and isolation through air pressure control [6].

The American Society of Heating, Refrigerating and Air-Conditioning Engineers Standardized through ASHRAE Standard 55-2013 thermal comfort as being the thermal condition that expresses satisfaction with the environment, having physiological and psychological variations among individuals, and it considers six main factors for thermal comfort of the building users: metabolic rate, clothing, air temperature, radiant temperature, air speed and humidity [7]. Defined as adaptive comfort, it derives from the view of the occupant as a fundamental component on the comfort of a building. This Method utilizes the Predicted Mean Vote (PMV) and the Predicted Percentage of Dissatisfied (PPD). For this calculation it was taken into account the outside dry-bulb temperature and operative temperature, defined as the uniform temperature of an imaginary black enclosure in which an occupant would exchange the same amount of heat by radiation plus convection as in the actual non uniform environment, establishing a temperature range for the sensation of thermal comfort by users [7]. Such comfort index would suit 90% of the users, this percentual would be of 80% [8].

2. Method

For this article, the following methodological stages were observed: building characterization through architectural survey and on-site visits; climate characterization of the surroundings using climate data provided by Instituto Nacional de Meteorologia (National Institute of Metrology), concerning the period from 2000 to 2010, updated by Roriz (2012), *EPW (EnergyPlus/EPSr Weather) from Santos Dumont Airport in Rio de Janeiro, a computer model and thermo-energetic simulation [9,10].

2.1. Building characterization

The exploratory and quantitative research was done by analyzing two case studies: Hospital Universitário Gaffrée e Guinle and Hospital Municipal Lourenço Jorge, both located in Rio de Janeiro. The city has the following geographical coordinates: -22.9027800° latitude and -43.2075000° longitude, and 2,3m above sea level [11]. The hospitals were projected in distinct dates, though both have natural ventilation as one of the project premisses. The brazilian bioclimate zoning established by the Building Thermal Performance Standards Part 1: Definitions, symbols and units - NBR 15220/2005, divides the country into eight zones, being Rio de Janeiro part of zone eight. It has as project premise natural permanent cross ventilation, and in the hottest hours of the year passive ventilation is insufficient by standards [12]. According to the municipality compass rose, southeast winds are predominant during the day and west winds during the night (Figure 1).

![Figure 1. Annual wind statistics for Rio de Janeiro (days on the left and nights on the right). Projetee (2018).](image)

The first case study was Hospital Universitário Gaffrée e Guinle (HUGG), located in the west region of the city, with southwest-northeast implementation of the major façades and southeast-northwest implementation of the minor ones and four floors. It was inaugurated in 1928 with neo colonial style [13]. During its construction, the surroundings were in a real-estate expansion due to several factories in the proximities, having at that time only up to two-story buildings. Currently it is in a densely populated area buildings with a height of up to 12 floors (Figure 2).
Figure 2. Hospital Universitário Gaffrée e Guinle. Google Earth Pro, 2018.

The wards are far from the main body of the building, have a 4 (four) meter ceiling and windows over each bed, being this all over the building, promoting crossed ventilation (Figure 3a). The window frames have sheets of glass and shutters (Figure 3b), with 1,00m width x 2,91m high, being 10% of ventilation permanent due to the use of shutters (Figure 3c).

Figure 3. (a) Building air flow, (b) ward air flow - plan view, (c) window detail. Authors (2019).

The second hospital chosen as a case study was Hospital Municipal Lourenço Jorge (HMLJ), also in the west zone of the city. The building has the major façades towards the north-south directions, and minor ones towards the east-west directions. It is a one-story building and it is divided in 14 blocks interlinked by patios. Each block counts with large windows and doors to the gardens (Figure 4).

Figure 4. Hospital Municipal Lourenço Jorge. Google Earth Pro (2018).

The building ventilation is passive, based on crossed ventilation and the chimney effect. Being favored by the shape and wind traps in its roof, through angulations and operable frames all over the building roof (Figure 5a). Its wards are facing the external areas and have large frames facing the external yard, in addition to favoring natural light and ventilation. The frames are the tilting type and are fixed (Figure 5b), with harnessing of 30% of wind flow in accordance with the opening angle, as shown in figure 5c [12].
2.2. Development of the computer models and thermal-energetic simulation
The thermal-energetic simulation program chosen was DesignBuilder v5.5.0.12 integrated to the EnergyPlus 8.6 tool, which allows the edification modeling in the design phase and also the evaluation of buildings that already exist and with pre-set materials. The reason for the software choice was because of its friendly interface and the NBR 15.575-1 standards recommendation of the use of EnergyPlus as a simulation program [12]. For the study the climate file base referring to the 2000-2010 period updated by Roriz was used, the EPW (EnergyPlus/EPS Weather) from Santos Dumont Airport for the HUGG and the one from Vila Militar for the HMLJ due to climate similarity and site proximity to the chosen climate file [10].

2.2.1 Site, model characteristics and property. For the analysis of the climate conditions of the building EPW climate files were obtained by National Institute of Metrology, and only the studied wards surroundings were considered (Figure 6).

3. Results and Discussion
Figure 7 shows the annual result of operating temperature of hospitals with 100% open frames according to hospital project. It is noted that in the HUGG the months of June, July and September are below the acceptable comfort interval of 90%. The months of May and August are in the comfort zone of 90% and the others are within the level of 80% of comfortable users. In the HMLJ the months of January and December are within the acceptable 90% comfort interval and the other months of the year are within the 80% user comfort range defined by ASHRAE 55-2013 [7].
Through computer analysis, it was found that the shape and the openings of the hospital used as study met the projectual premise proposed for bioclimatic zone 8 that indicates the use of natural ventilation as the most suitable strategy to obtain thermal comfort, defined by building thermal development standards NBR 15220/2005 [14]. However, according to the National Meteorological Institute, average annual temperature in Rio de Janeiro, mainly in the summer is close to the maximum limit considered comfortable of 32ºC [9]. During the summer (December to March) the average temperature corresponding to the 1981-2010 period was 30.97ºC and during the winter (June to September), natural ventilation meets the expectations in providing comfort to the user since average season temperature is 26.7ºC.

4. Conclusion

In general, results show that, despite the high temperatures in Rio de Janeiro, the case study settings obtained favorable thermal-energetic results, taking into account the natural ventilation strategies adopted, providing thermal comfort for their users for the most part of the year (April to December).

It is advisable that in warmer months, when natural ventilation is insufficient to maintain comfort temperature, users may be able to operate the windows and air conditioning system, this means using mixed ventilation (natural or mechanical ventilation). And in the colder months of the year they can close off the windows to maintain comfort. The users the user that is allowed to operate the frames can control better the self-comfort.

It would be desirable for such research to be expanded with the use of nursing, questionnaires and interviews of the health staff.

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