Chapter 78

Sarah Kubitschek Hospital - Rio De Janeiro: a study on ventilation and air renewal

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ABSTRACT

The relationship between architecture and air quality is observed in different moments in history and was evidenced during the pandemic of COVID-19, since there is a direct relationship between the building, the openings, air renewal and how these factors affect the user's health. In this sense, this work aims to analyze ventilation systems in hospital areas, especially infirmaries, places susceptible to contamination by airway infections. The methodological procedures start from a literature review and have as a case study the infirmary of the Sarah Kubitschek Hospital in Rio de Janeiro, with the analysis carried out through computer simulations. The research demonstrated the importance of different types of ventilation in different spaces within a hospital, as well as the need for air renewal as a promoter of the environment's salubrity, and patients' well-being, a strategy applied by João Filgueiras Lima in this hospital. The analyses show that such strategies contribute to maximize natural ventilation promoting greater natural air renewal and user comfort.

Keywords: hospital architecture, air quality, ventilation.

1 INTRODUCTION

The impacts of climate change have been felt by society and the scientific community, in this sense it is observed that there is a prediction of an increase in global temperature by 2 ° C, if this occurs nature runs serious risks (BBC, 2020). In large urban centers, the impact is observed in greater severity, however, the man had been seeking solutions to protect themselves from this increase in temperature without worrying about sustainability. Among these means of protection, artificial air conditioning has become an ally to reduce the human discomfort inside buildings, disregarding the passive techniques that value the elements of nature in the project, such as natural ventilation.

New technologies have driven the verticalization of cities, allowing people to spend most of the day in enclosed spaces, with little contact with nature. Therefore, it was necessary that buildings could provide comfort and air quality to their users. In 1902, the American engineer Willis Carrier created air conditioning, enabling the control of temperature and humidity in airtight environments, however, these buildings began to consume high levels of energy. In the early 1970s, the energy crisis brought the need for savings, therefore, to reduce the cost of air conditioning, the practice of recycling the air inside the building was adopted. These actions increased considerably the discomfort index of the occupants and, with the costs of absenteeism[1] , leading specialists to study the causes of these diseases. As the buildings became more and more hermetic, air renewal was impaired, and to this was added the use of polluting products and materials inside the spaces, resulting in increasingly contaminated internal environments, which we now know as Sick Building. According to Melo (1991), the human being is influenced by space, and the way it is designed positively or negatively affects people's quality of life. Therefore, if the project does not present a qualitative environmental comfort in lighting, acoustics and ventilation, the places may cause stress in its users, and this issue becomes even more important when dealing with hospitals, which are places intended for healing and recovery. That said, environmental quality has been directly affecting humans, who, in the recent past, were not integrated environmental considerations in the design and construction. Keeler and Burke (2010) also relate the Sick Building Syndrome (SED)[2] to poor indoor air quality, generating health problems, loss of productivity, etc. In the United States, in 2010, a study analyzed that the definition of parameters for a higher indoor air quality reduces expenses in an annual value between "tens of billions of dollars". In this context, bioclimatic architecture is present when harmonizing the construction with the environment, taking advantage of local characteristics for the best building performance.(KEELER; BURKE, 2010). Although there is an increase in the concern with the quality of the environment, since the creation of qualitative standards and sustainable strategies, it is clear that there are still few professionals who master these practices, especially in hospital environments. Facing the pandemic caused by the coronavirus, it is possible to observe that natural ventilation is a fundamental issue to promote the quality of the internal environment and health. In the Folha magazine article entitled "Lack of ventilation and mold increase the risk of infection in 11 million homes", it is observed the concern with the EDS by pointing out that the precariousness of the buildings compromises the occupants' health (REIS, 2020). Facing the coronavirus crisis, the architect and urban planner Thomas Vonier, president of the UIA (International Union of Architects), published a note on the importance of the performance of these professionals facing this moment. The UIA was created in 1948, a time when the world was recovering from the Second World War. In addition to highlighting the role of the UIA, which continually strives to improve human conditions and the preservation of natural resources, Vonier (2020) points out: And that is what we need today - first, to help the world fight the deadly pandemic, and then to help communities recover and rebuild, applying lessons learned that will help prevent future environmental and health catastrophes. (...) it is our role to highlight relevant research, promote information sharing, and advocate for good policies. (p. 1 Free translation) ANVISA National Health Surveillance Agency (2020), also presented a note[3] regarding the use

[1] According to the Michaelis dictionary, absenteeism is the "habit of being absent from one's home or job. It can be caused by work deficiencies, illness, financial, family, transportation, and other reasons. Generally speaking, absenteeism reveals that something unfavorable to the employee is happening

[2] The Sick Building Syndrome (SED) was recognized in 1982 by the World Health Organization (WHO)

[3] Technical Note Nº 3/2020/SEI/CIPAF/GIMTV/GGPAF/DIRE5/ANVISA Process No. 25351.910936/202043 20

of air conditioning systems at ports, airports, and border crossings during the COVID-19 pandemic, the data highlights that air conditioners are disseminators of contaminants. The agency also points to the verification and even suspension of the use of the devices, especially in cases of systems that do not have the outside air as a source of air renewal. Having said all this, in hospitals, there are strict rules and the need to understand the uses to avoid contamination, among them: physical barriers, filters and good natural ventilation in agreement with Toledo (2020, p. 1)

> I am sure that, more than ever, it will be necessary to revisit the work of João Filgueiras Lima, especially the hospitals of the Sarah Network, where Lelé developed construction methods that ensured great flexibility and economy in the sometimes radical modifications of hospital environments. With the use of ventilation and natural lighting and the landscape that seems to penetrate the interior of the Network's hospitals to join the internal gardens, Lelé gave us a clue as to how the hospitals of the future should be.

Thus, this study based on the work of the architect Lelé, becomes of great importance for the current scenario in which we live. Architecture becomes a fundamental tool for improving the quality and well-being of the internal environment, because it is the one that relates and integrates the norms with the physical needs of the human being, to create spaces with environmental quality.

The objective of this work is to study hospital ventilation systems, especially natural ventilation as one of the factors that promote the quality of the internal environment, by means of air renewal. The study focuses on the hospital environment, especially the infirmary of the Sarah Kubitschek Hospital in Rio de Janeiro (RJ).

2 METHODOLOGICAL PROCEDURES

The methodology used for the development of this work was done in two stages:

Stage 1 consists of Theoretical foundation; Literature review of sustainable and bioclimatic strategies; Study of national and international standards that assess health issues in hospital areas

The RDC nº 50/2002-Norms of Physical Infrastructure for EAS (2002); Norm 55-2004 (2004) - ANVISA; The Brazilian norms: NBR 7256 (2005) Air Treatment in Health Care Establishments (EAS): Requirements for Project and Execution of the Installations; NBR 16401-3 (2008) Installations of air-conditioning: Central and unitary systems. Part 3: Indoor air quality; NBR 15220 (2005) Thermal Performance of Buildings Part 3: Brazilian Bioclimatic Zoning and constructive guidelines for single-family houses of social interest; The international standard ASHRAE 55(2004)*Thermal Environmental Conditions for Human Occupancy, of the American Society of Heating, Refrigerating and Air-Conditioning Engineers*.

Stage 2 consists of a case study of the infirmary room of the Sarah Kubitschek Hospital in Rio de Janeiro, designed by architect Lelé:

1. Analysis of articles, dissertations, and theses already published; Analysis of the strategies used by Lelé, which provide user comfort and reduced environmental impacts.
2. Simulation with ANSYS-CFX programs

3 CASE STUDY

3.1 THEORETICAL FRAMEWORK: LELÉ AND THE SARAH NETWORK

This topic presents an analysis of the Sarah Kubitschek Hospital in Rio de Janeiro, as well as the comfort strategies adopted by Lelé and a study of the ventilation systems in this hospital, specifically in the Sarah Rio ward.

João Filgueiras Lima, known as Lelé, became known for his projects in the Sarah Kubitschek Hospital Network, but he also worked on the construction of Brasília and on the development of reinforced mortar with the mass production of prefabricated buildings. The architect is from Rio de Janeiro, born in 1932, and graduated in Architecture in 1955 from UFRJ (Federal University of Rio de Janeiro), former University of Brazil. His architectural influences are Aldari Toledo, Oscar Niemeyer and Alvar Aalto, and according to Lúcio Costa, Lelé came to "fill a gap in the development of Brazilian architecture" (ROCHA, 2011 p. 75).

His work in hospital architecture was influenced by Aloysio Campos da Paz, whom he met in a car accident. Faced with Aloysio's humanistic vision of treating each patient individually and the idea that medicine is an instrument of healing, Lelé identified with this vision and began to apply it to his hospital projects.

Thus, Lelé's work goes far beyond architecture and construction. As an architect he thinks of the user as a person and not as a design element, this is clear in his statement ... "I think of the patient, the frail human being who seeks a hospital" (RONCONI; DUARTE, 2007 p.21). One can see that when designing an environment as peculiar as a hospital, Lelé has had results internationally recognized as exquisite, an example of this design result is the Sarah Rio de Janeiro, the Network's latest project. As shown in figure 1.

Figure 1: View of the Sarah Rio Hospital

Source: http://arquitetablog.blogspot.com/2011/06/joao-filgueiras-lima-lele.html Accessed on 23.04.2020

Throughout his career, Lelé became more critical and had a greater command of bioclimatic conditions. This concern with comfort and energy saving is manifest in his latest projects. In the hospitals of the Sarah Network, this becomes extremely clear, based on the climate of each city, Lelé designed alternatives to improve the environmental comfort inside the hospitals, combining the passive techniques of each region, such as *sheds* and ventilation galleries, strategies that he learned on a visit to Europe and adapted to the Brazilian climate (PEREN, 2006).

According to Lukiantchuki and Caram (2014) the works of the Sarah Network are recognized worldwide as examples of bioclimatic architecture, because it goes beyond human comfort, but also sought energy saving issues and techniques that cause the least environmental damage.

In agreement, Perén *(*2006, p. 35) points out some of these characteristics:

> Naturally lit and ventilated spaces, with wide ceiling heights and devices to cool them, such as ventilation galleries with foggers and water mirrors, as well as the incorporation of internal gardens, are some of the resources Lelé proposes to generate more humanized spaces, with few artificial air conditioning resources and, therefore, low energy consumption. The shaded roofs, arranged to take advantage of the light and facilitate the natural ventilation of the spaces, are one of the most striking and present characteristics since his first works, still in Brasilia.

The hospital of the Sarah Rio do Janeiro network, 2009, is considered according to Boni, Silva and Fortuna (2018, p 84.), the masterpiece of the whole network, once being the newest hospital, the problems found in the previous ones were solved in a better way in Sarah Rio. As Lelé himself says in an interview:

> Today, for example, in Rede Sarah, it is a laboratory and every day the spaces are corrected, sometimes by mistakes, and sometimes even by the evolution of technology itself that requires greater flexibility in use (...) Architecture is a process, not a design, architecture is this coexistence that will occur over many years; in my case, I am mentioning this project, but there are many others involving this coexistence, from the first design to the modification that happens over the years. (RONCONI; DUARTE, 2007, p.23)

Marques (2012) compares Lelé's works with Charles Darwin's concept of evolution in the book *The Origin of Species*, by stating that Lelé's architectural solutions "survive" by being adapted to the climate. In this project the flexibility allows the change of layout, it has other peculiarities such as:

- *Sheds* for natural lighting and ventilation;
- Tilting linings that open and close according to need;
- A technical floor where evaporative cooling takes place;
- Brises to control the incidence of sunlight;
- Hybrid ventilation can take place in three ways, natural, artificial, or mechanical.

For all these reasons, the Sarah Kubitschek Hospital in Rio de Janeiro was chosen as the case study for this research, especially its infirmary room.

3.2 THEORETICAL FRAMEWORK: SARAH NETWORK RIO DE JANEIRO

Opened in May 2009, the Sarah Kubitschek Hospital in Rio de Janeiro was the last unit to be built and focuses on the motor rehabilitation of patients (ROCHA, 2011). As figure 2 highlights.

Figure 2: Top view Sarah Rio

Source: Photo Leonardo Finotti Available at http://www.leonardofinotti.com/projects/sarah-rio-hospital/image/18312-100508-002d Accessed on 23.04.2020

Table 1: Datasheet

FICHA TÉCNICA	
Nome do Projeto	Centro Internacional Sarah De Neurorreabilitação e Neurociências
Local	Av. Embaixador Abelardo Bueno N. 1500 – Jacarepaguá – Rio de Janeiro – RJ
Autor	João Filgueiras Lima (Lelé)
Uso	Hospitalar
Data de Projeto	2001
Data de início da obra	2002
Data prevista para a finalização	2009
Área do Terreno	87.000 m²
Área Construída	54.376m² (incluindo o pavimento técnico)
Conforto Térmico	George Raulino

Source: ARCOWEB, 2020

At first, the Hospital and the Children's Rehabilitation Center were to be implanted on the same land, but they would occupy 80% of Pombeba Island, so legislation prevented the construction, so that each unit was implanted in different locations. The units are connected by Avenida Embaixador Abelardo Bueno, and are close to the Jacarepaguá lagoon. As shown in figure 3 taken from Google Earth.

Figure 3: Child Rehabilitation Center marked in yellow and Sarah Hospital marked in red

Source: Google Earth with author's edition

The Sarah Network, financed by the Ministry of Health, was born through the *progressive care* system, in which each patient's evolution leads to a change of room, which helps the patient both in medical procedures and in their psychological comfort. For this project, more than technical knowledge in architecture was needed, so Lelé relied on the opinion of health professionals to develop it. As already mentioned, in his works there was a concern with low cost and environmental preservation, with the use of natural resources, even before sustainability became a recurring theme. Thus, green spaces, use of natural ventilation and lighting, and comfort are aspects present in his works as part of his characteristic of humanizing hospitals. In addition to the use of integrated gardens and works of art, Lelé strategically inserts environmental comfort (ROCHA, 2011).

Another aspect that shows the concern with the environment is the use of steel, plastic, and reinforced mortar produced at the Sarah Network Technology Center, which, due to their practicality in assembly, guarantee organization and cleanliness at the construction sites.

Perén (2006) points out some guidelines that guided the design of this hospital:

- More flexible layout of the internal spaces in relation to the other units of the Sarah Network;
- Horizontal architectural party;
- Create a technical floor along the entire length of the hospital;
- Internment areas integrated with green spaces;
- Natural lighting and ventilation systems;
- Coverage independent of the internal installations;
- Create a flexible ventilation system, with three ventilation alternatives: natural, mechanical, and air-conditioning, always prioritizing natural ventilation.

Figure 4: Rio de Janeiro's Sarah Roof Structure

Source: Photo Ricardo Buso and Sheila Altmann, Rio de Janeiro, 2004 apud ROCHA, 2017

In this ventilation system created by Lelé, *shaded* roofs were designed, with variable dimensions and positioning unrelated to the internal organization. In figure 4, it is possible to observe the roof structure in *sheds*, as a separate element of the complex. This feature always provides layout flexibility. In the roofs, there are also flexible closing systems, which allow for different ventilations according to climatic needs, without hindering the entrance of natural lighting.

3.3 THE ANALYSIS OF SARAH RIO'S ARCHITECTURE AND TYPOLOGY

The Sarah Rio de Janeiro Hospital is characterized by a horizontal architectural party. The flat terrain was one of the facilitators, and the horizontal solution is a design choice of Lelé, who comes from several other hospitals. This party facilitates the interconnection between the blocks, as well as the locomotion of the patients, since it is a hospital focused on the recovery of the motor apparatus.

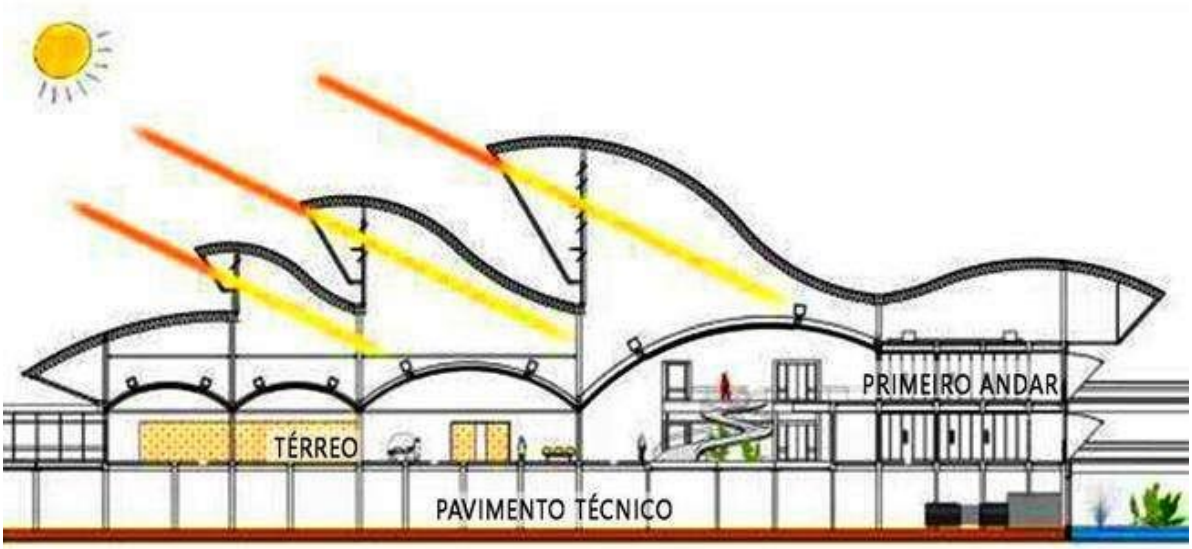
The Rio hospital complex has a built-up area of almost 55,000 m² and a capacity for 120 beds. The complex was divided into 5 blocks (figure 28): 2 for services, an outpatient clinic, an inpatient block, and an auditorium. These blocks are interconnected and surrounded by gardens and water mirrors, elements that make the stay of employees and patients pleasant, promoting visual comfort, and improving the microclimate of the complex (LUKIANTCHUKI, 2010).

Figure 5 : sectorization of the Sarah Kubitschek Hospital Complex

Source: PEREN, 2006 (adapted by the author)

Even though it is a horizontal hospital, it is not a building with only one floor. Although it is mostly a first floor hospital, there are some sectors that are below the implantation level, such as the technical floor, the study center, and part of the auditorium. There are also individual apartments, which are located on the second floor (figure 6). These apartments have an external balcony, besides the access to the solarium, which is located on the water mirror. The access to the apartments is through the central ramp, which is located in a large lobby with an internal garden, revealing once again the concern with the feeling of not only environmental comfort, but also visual comfort that Lelé seeks in his designs (PEREN, 2006).

Figure 6: Section showing Sarah Rio floors



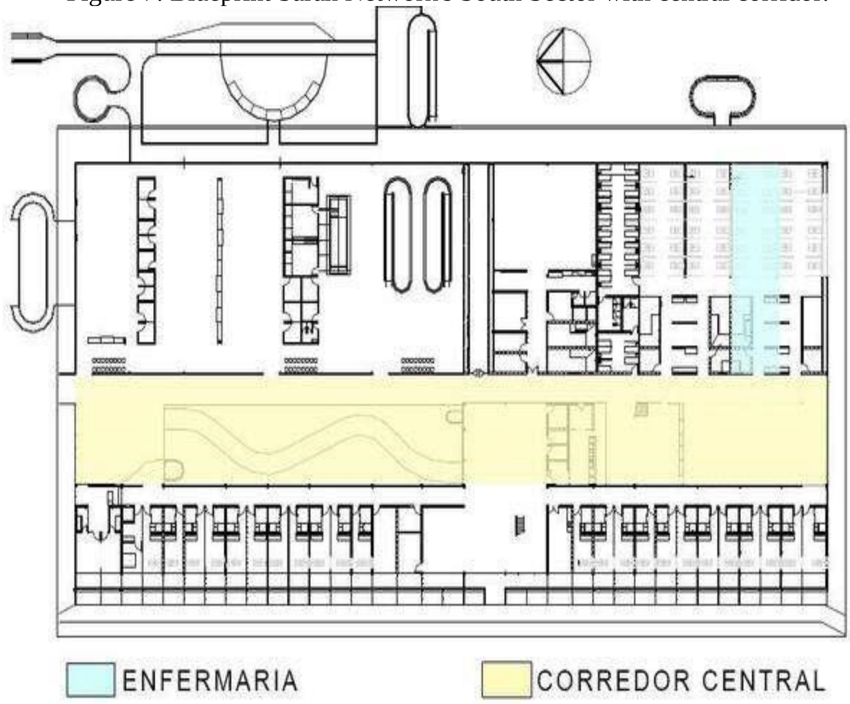
Source: Image taken from the video "Video-animation about the construction of the Sarah Rio Hospital - Arch. Lelé available at https://www.youtube.com/watch?v=sxdfitXCFXg Accessed on 14/01/21 (adapted by the author)

If we compare the design of the Sarah Rio with the types of layouts presented by Chartier and Silva (2009), we can say that this hospital has an internal corridor layout, because when we observe it, there is a large central corridor, dividing the volume into two parts. On one side, there are the wards, physiotherapy rooms and indoor swimming pool, and on the other side of the corridor are the individual apartments.

By looking at the hospital's cut and analyzing the way the ventilation happens, we can say that the *sheds* function as a wind tower in natural ventilation, and in this case, fresh air enters through the *louvers* on the east side of the *sheds*. The air then descends into the rooms and exits through the west façade. In forced ventilation, we can say that the *sheds* function as an atrium or chimney, since the fresh air, which comes from the technical floor, is blown in through the louvers and pushes the hot air upwards. This type of ventilation prevents cross-contamination.

Sarah Rio Hospital has a large central corridor, interconnected with the air "pocket" that is between the *sheds* and the ceilings. These spaces act as a sink for contaminated air. Knowing that hot air rises, when cold air is blown into the rooms, the hot and contaminated air is carried through this large central atrium to the "air pocket", where it is removed from the building. This process occurs in both natural and mechanical ventilation.

Figure 7: Blueprint Sarah Network's South Sector with central corridor.



Source: Plants from LUKIANTCHUKI, 2010 (adapted by the author)

3.3.1 The sarah network ventilations

Concerning ventilation, as mentioned, the hospital complex has three types: natural, forced, and air-conditioning, which can be activated according to the need or weather conditions of each day.

Although Lelé prioritized natural ventilation, there are some sectors where the use of air conditioning is essential and the only form of ventilation, as in some rooms of the outpatient block, as shown in figure 8. In the eastern service block, there is only natural ventilation. In the next block, there are rooms with three ventilation options and some rooms with only natural and forced ventilation. In the outpatient block, as mentioned, there are some rooms in which the only form of ventilation is by air conditioning, and in the rest of the rooms, there are three forms of ventilation. In the inpatient block and in the auditorium, any of the ventilations can be used according to the users' needs.

Thus, it is possible to observe once again the architect's concern in using bioclimatic techniques for environmental preservation, cost reduction, and user comfort.

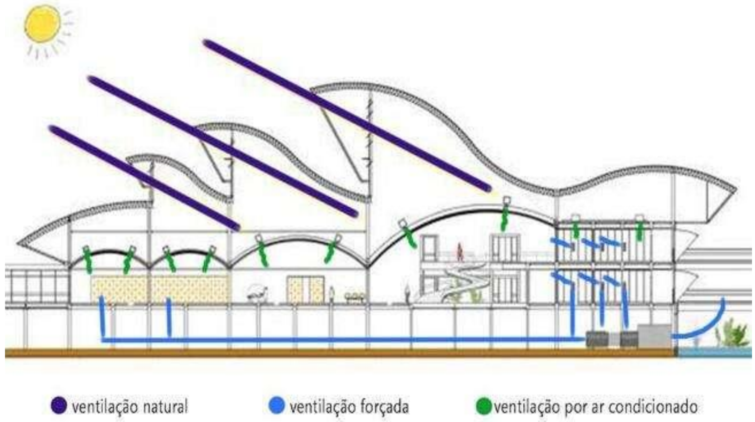
Figure 8: Sarah Rio Ventilations

Source: PEREN, 2006: LUKIANTCHUKI, 2010 (adapted by the author)

For this ventilation to take place, a large infrastructure was thought of. As already mentioned, natural ventilation comes through the openings in the *sheds* and the windows present in the rooms. The forced ventilation comes through the technical floor, and the air is blown in through the walls and enters the rooms through shutters. The air conditioning is arranged in metallic structures, which form arches throughout the complex, and its ducts pass through these structures, while the air vents are found in these arches.

It should be noted that a system that contributes the most to comfort is the hospital's roof,which is formed by large *sheds* with variable ceiling height. Between the lining, made of tilting pieces, and the covering, there is a large ventilated air cushion, and both minimize the impact of temperature, besides being a light diffuser for the internal environment, bringing comfort. Besides the *sheds*, there is a flexible system in the lining, a mobile arc that is closed or opened, as the climate and temperature of the city vary (ROCHA, 2011).

Figure 9: Ventilations at Sarah Rio Hospital

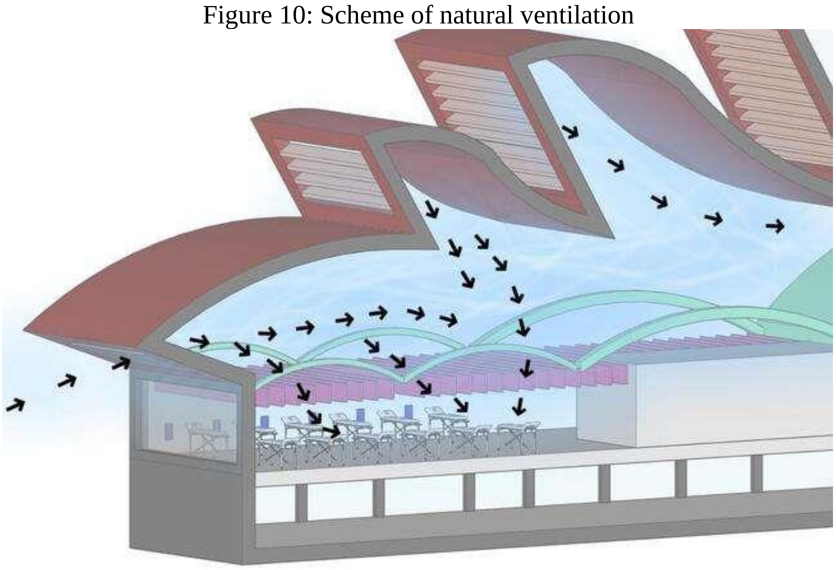


Source: Image taken from the video "Video-animation about the construction of the Sarah Rio Hospital - Arch. Lelé available at https://www.youtube.com/watch?v=sxdfitXCFXg Accessed on 14/01/21 (adapted from author)

The natural ventilation occurs due to the use of the predominant winds from the east face, because the hospital was implanted in a way that the wind enters through the hospital and leaves from the west side. Moreover, the format of the *sheds*, the windward and leeward contribute for this ventilation to run in the best way in the hospital (PEREN, 2006).

When there is the presence of wind, it passes through the *brises in* the *sheds*, allowing air to enter the hospital. The curved ceiling, the ceiling of the central corridor, is retractable, which is open, as well as the hinged ceilings, allowing fresh air to enter and descend into the rooms. As the west façade has openings in the *sheds* and windows, air flows inside the hospital minimizing heat and removing impurities from the air. Figure 10 shows a schematic in which the arrows are initial analyses of the wind intakes in the ward in the different ventilation systems, so they are qualitative and without a precision of the airflow that will occur inside the building, such flows will be indicated in the computer simulations.

Figure 10: Scheme of natural ventilation



Source: Production by the author

On the other hand, mechanical or forced ventilation happens by means of evaporative cooling, which occurs through the technical floor, positioned on the opposite side of the prevailing winds, actually forcing ventilation.

Evaporative cooling occurs when natural air is cooled and sucked into the hospital. The envelope, which separates the inside and outside of the technical floor, is composed of a perforated aluminum panel (figure 11). Behind these panels, there are fans to capture the air. Thus, the air, which will be sucked in, is cooled when it passes through the water sprinkling system (figure 11) present in the water mirror (LUKIANTCHUKI,2010).

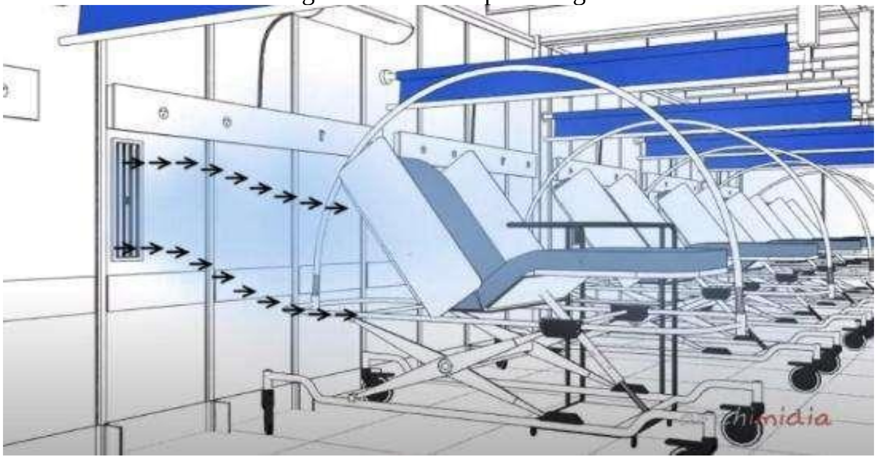
Figure 11: Air intake on technical floor and perforated panel respectively

Source: PROJECT, 2009: http://ceres.sarah.br/dimensaometacognitiva/Pages/05d-RIO.html Accessed on 09/02/2021 (adapted by the author)

In this way, the cold air that runs through the technical floor enters the pipes present between the double walls made of reinforced mortar and exits through the blinds, scattered in various rooms of the hospital. These shutters are movable and are opened or closed manually according to the user's needs. In previous hospitals, the blinds were close to the ceiling or floor, which made handling them more difficult. In the Rio hospital, this problem was solved by positioning the blinds in the middle of the walls at 75 cm from the floor.

In the wards, the blinds are arranged vertically and there are "twelve blinds", one for each patient, as shown in Figure 12. In other rooms, such as kitchens, changing rooms and hydrotherapy room, the openings are arranged horizontally. In the kitchen, they are at the height of users and, in the other two environments, they are close to the floor, for better comfort, since each environment has a different type of activity (LUKIANTCHUKI,2010).

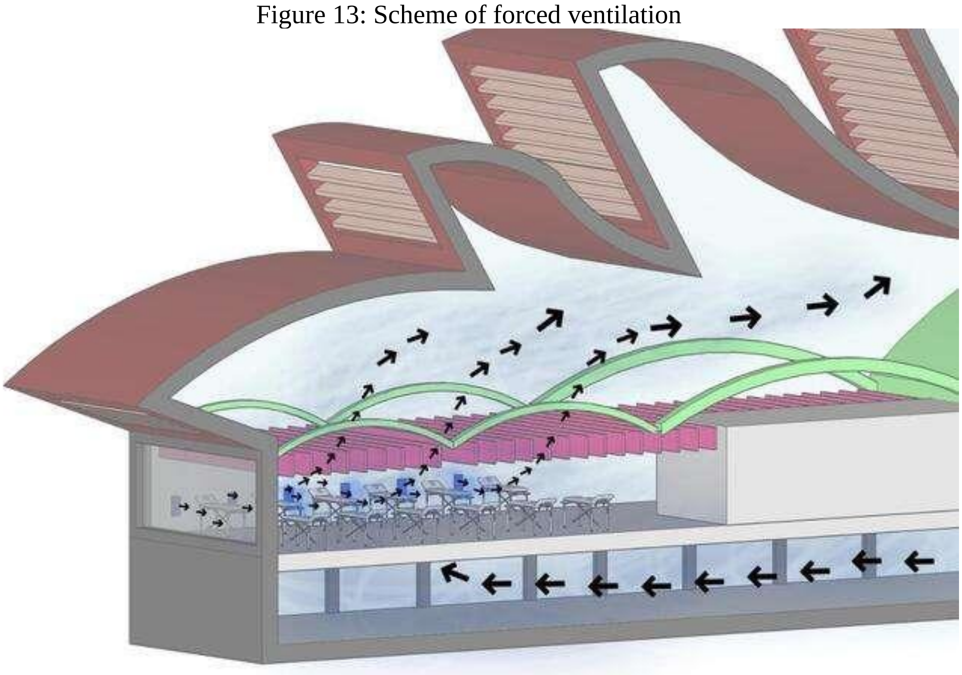
Figure 12: Air escape through the louvers



Source: Image taken from the video "Vídeo-animação sobre a construção do Hospital Sarah Rio - Arq. Lelé", available at https://www.youtube.com/watch?v=sxdfitXCFXg Accessed on 14/01/21 (adapted by the author)

After the cooled air enters the room, it pushes the warm air, which passes through the moving linings in the roof. Through the removal process, the warm air leaves the building from the west (leeward) side as shown in the following diagram in figure 13 (PEREN, 2006).

Figure 13: Scheme of forced ventilation

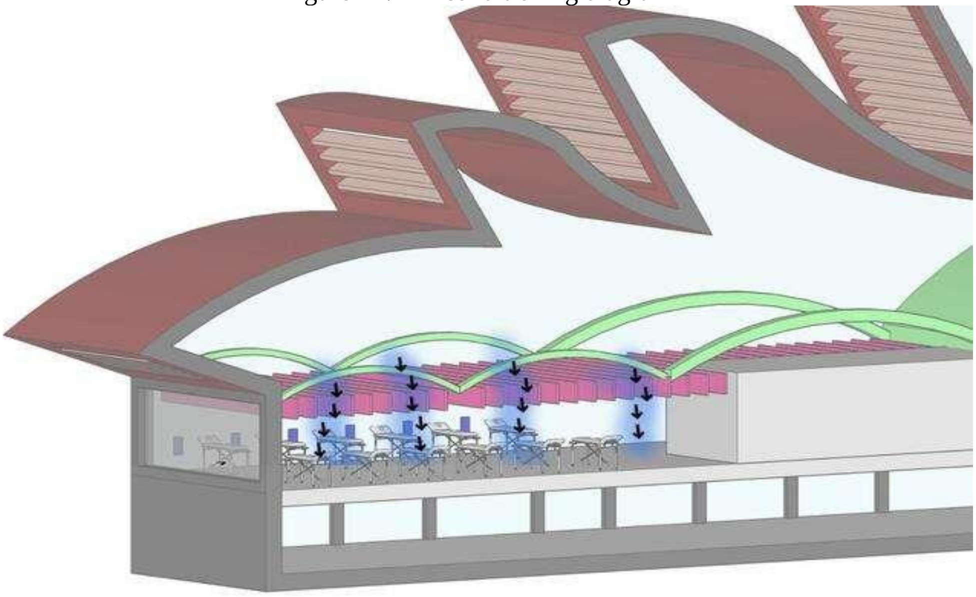


Source: Production by the author

Finally, for the hottest days, when neither natural nor forced ventilation is sufficient to maintain comfort inside the hospital, the use of air conditioning becomes necessary. In this case, the ceilings and the blinds are closed so that the air can be turned on. The air-conditioning system is done by *fan-coil* type units, the ducts, through which the air passes, are hidden between the double walls of reinforced mortar and in the roof beams. The air vents are located at various points of the arches throughout the hospital, as shown in Figure 14 (LUKIANTCHUKI, 2010).

The air cooled by the air conditioner is also captured by the technical floor and, instead of blowing it into the louvers, it is directed to the *fan-coil* units (figure 14). On extremely hot days, the air-conditioning system is supplied with chilled water.

Figure 14: Air-conditioning diagram



Source: Production by the author

Having said all this, it is known that the quality of the environment is influenced by several factors, two of which are indoor air quality (IAQ) and environmental comfort. According to the parameters presented for obtaining comfort, indoor air quality and, finally, indoor environmental quality, it can be said that the Sarah Rio hospital complies with the requirements, by providing ventilation for removing impurities and renewing the air, besides maintaining comfort, natural lighting, vegetation and all the bioclimatic elements that promote comfort, reduce patient stress and promote a shorter recovery time, since the hospital environment has become a pleasant environment, this being one more way to evaluate comfort. Since the determination of comfort is something personal, to the extent that there are physical and psychological reactions, showing improvement and satisfaction, it can be said that comfort was achieved(BITENCOURT, 2014).

When dealing with the infirmary, it is possible to observe that its dimensions are above the minimum parameters established by the norms for the promotion of salubriousness and air renewal. Its air inlets and outlets promote cross-ventilation, essential for the minimization of cross-infection contagion. In addition, the three types of ventilation help in the comfort during the year, one supplying the other according to the climatic needs of the day. Since Indoor Air Quality is much more than a quality classification, but rather a component of comfort and health preservation, it is possible to say that the Sarah Rio can be classified as an indoor environmental quality environment.

3.3.2 Computational Simulations

This section will present the simulations performed with the Ansys-CFX programs, as well as the results and analysis made from this

3.3.2.1 Natural and Indoor Ventilation with Ansys - CFX

There are several methods for analyzing natural ventilation and indoor air renewal and according to Leite:

> Methods range from simplified algorithms to physical model testing, to zonal models embedded in thermal performance programs, to the complexity of CFD codes, which bring together the conservation equations for mass, momentum, and energy based on the solution of the transport equation, allowing the behavior of airflows at different scales to be described. (2015, p. 90*)*

For this research, we adopted Computational Fluid Dynamics, known as CFD (Computational Fluid Dynamics), through the program Ansys-CFX. The tool allows the study and analysis, among several, chemical reactions, heat transmission, gas concentrations, and for this research, the behavior of fluids, in particular, the behavior of winds.

The program produces faster results when considering experiments in the real research environment. Not to mention that measurements in indoor environments with people are not always possible, especially in places like hospitals, where infection is always high and the inconvenience for the user is also high. For all this, computer simulation was adopted as the method of analysis for the case study.

The simulation takes place in five steps. First: the modeling of the geometry to be analyzed, followed by the generation of a mesh; then, the boundary parameters, wind direction and pressure, openings, among others, are determined, and finally, the calculation and visualization of the results.

The first step was to define the environment to be analyzed. The ward was chosen because this location has the three types of ventilation and because it is a place with a considerable number of people concentrated, being 12 patients and 4 nurses[4] , which facilitates contagion among people, requiring more attention to care for the air in this environment. In addition, this sector has more information available, such as blueprints, sections and measurements needed for the simulation.

[4] The number of 4 nurses was established based on COFEN Resolution 293/2004, and COFEN Resolution 543/2017 which establishes the minimum team of 1 nursing technician for every 4 patients and 1 nurse for every 12 patients in Intermediate Care (neuro rehabilitation and motor difficulty - specialty of Sarah Kubitschek Hospital Rio de Janeiro)

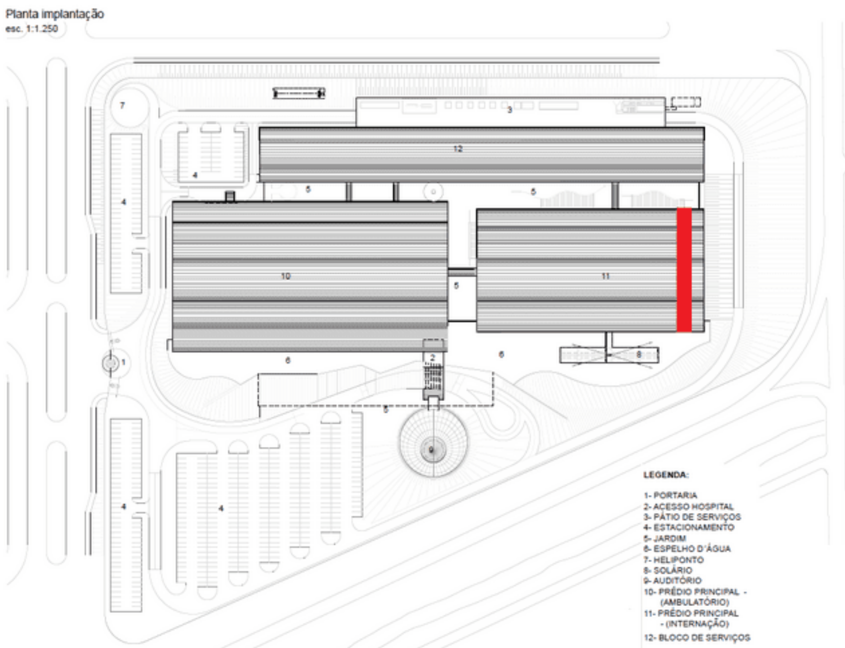
Figure 15: Picture of the empty ward

Source: LUKIANTCHUKI,2010

The ward analyzed is located in the inpatient block, to the south of the hospital complex, as shown in Figure 15. The face that borders the exterior is on the east façade, the side that receives the greatest amount of wind, coming from the southeast, and also receives an abundant amount of natural lighting. As mentioned, each ward room has a maximum capacity of 12 patients. Each bed has exclusive lighting and shutters, and partitions were designed to go up and down, according to each patient's need for privacy.

One characteristic of the infirmary is the absence of doors; the entrance to the infirmary takes place in the corridor that cuts across the entire block. In the same way as other rooms, the infirmary has tilting ceilings and air conditioning outlet points. The plan in Figure 16 shows the infirmary in red.

Figure 16: Deployment and chosen sector



Source: PEREN,2006 (adapted by the author)

Dealing with the simulations, in the first moment (SIMULATION 1), the volumetry of the entire hospital complex was modeled, to simulate and extract the necessary data for the second simulation, (SIMULATION 2) which shows the effects of ventilation within the chosen section. The modeling was done in the AutoCad 3D program. The volumetry was modeled in a simplified way, to facilitate the development of the simulations. With the volume ready, the file was exported in .sat format for use in the program Ansys-CFX.

In this modeling, there must be a domain that is nothing more than a volume, where all the elements and objects are contained, and in which the result of the fluids and simulation are represented. Given that the Sarah Rio hospital complex is located in a distant land and with almost no blockage for the passage of wind, as shown in the image of figure 17, only the hospital volume was left within the domain. For the modeling of the domain, the rectangular shape was chosen, in general, the domains can be made in various geometric shapes, however, according to Leite (2015), "a rectangular domain has the advantage of having a mesh generation with a smaller number of elements and is also used when it is intended to simulate only one direction of incident wind". As a standard, it is adopted measures of five times the height of the largest element present, from this to the windward, lateral and top limits, and for the leeward region the measure of 15 times.

Figure 17: Aerial view of the Sarah Rio de Janeiro complex

Source: Google Earth, 2021

3.3.2.2 External Ventilation

In Simulation 1, the data analyzed were the incident pressure on the facades and the wind action through the hospital complex. This simulation was necessary because it was necessary to know with what speed and pressure the winds reach the facades and consequently enter the hospital.

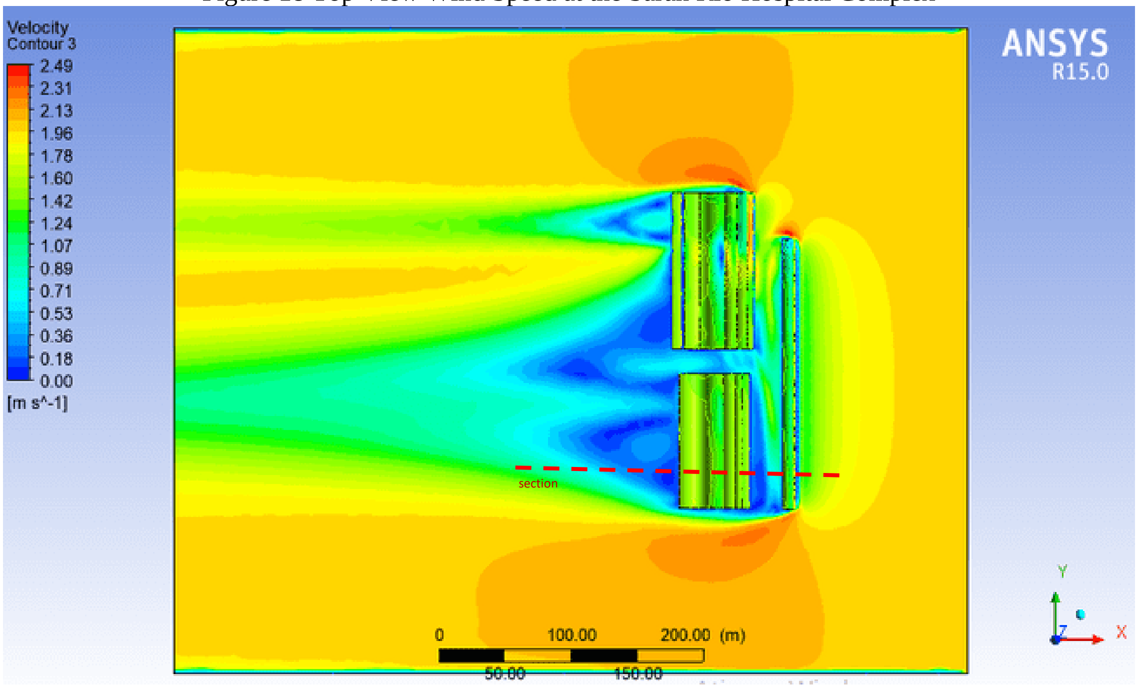
For this simulation, Fluent Flow (CFX) was used, and some data were adopted. For ventilation, a velocity of 2 m/s was considered since according to the Wind Rose, this was the most constant velocity on the east façade; for air temperature, 25 °C was adopted; the turbulence model was *k-epsilon*.

The model was organized in the following manner: the hospital complex was called object, the lower face of the domain was considered floor, the side and upper faces were called wall, the windward face was considered inlet, and the leeward face as outlet. In the inlet, a velocity of 2 m/s was applied, and in the outlet a pressure of 0 Pa. Thus, the simulation was set to run.

The simulation results allowed the extraction of some data such as the pressure at each point of the complex, as well as the behavior of the wind around it, both in plan and in section.

In Figure 18, it is possible to observe one of the results of the simulation that is the wind action through the complex. Note the behavior of the wind coming from the east following to the west. It is notable the effect that the volume of the hospital causes in the wind, by changing its direction, coming from the east, the speed increases on the north and south facades, and on the west facade there is a low speed. It can also be seen that the building acts as a wind speed reducer. In addition, this volume causes a large wake and turbulence effect on the west façade, even if at reduced speed.

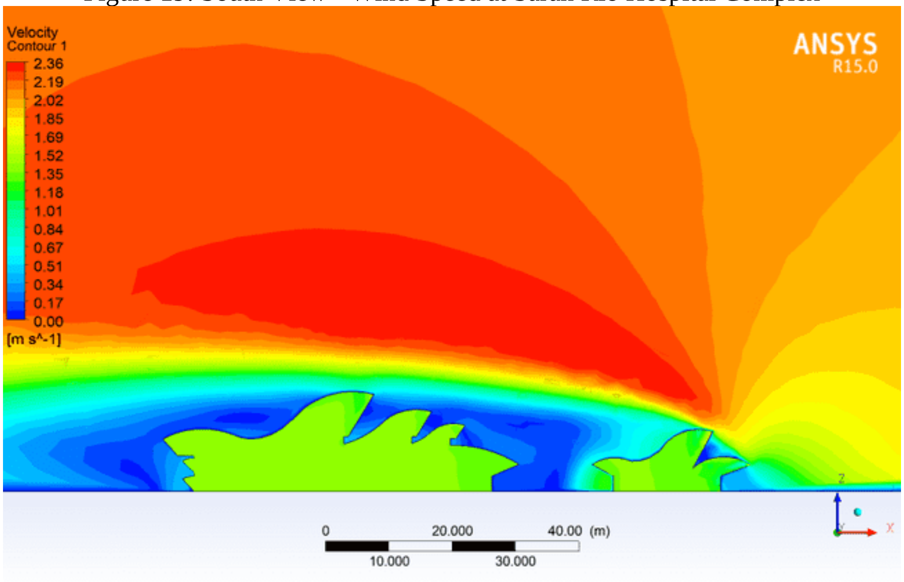
Figure 18 Top View Wind Speed at the Sarah Rio Hospital Complex



Source: Ansys 15.0 Production Author with support from Nazareth

In Figure 19, we see the result of the wind action from another perspective. A section was made in the infirmary area. As can be seen, the image shows that the volumetry of the hospital, once again, acts as a modifier and attenuator of the wind speed, through the blocks. The smaller (service) building acts as a barrier to the winds, and the speed that reaches the larger building is quite low. It is possible to conclude that this barrier prevents a strong wind from entering the ward, which would cause discomfort to the patients due to the high speed.

Figure 19: South View - Wind Speed at Sarah Rio Hospital Complex



Source: Ansys 15.0 Production Author with support from Nazareth

As shown in Table 2, air velocity exceeding 1.5 m/s according to Olgyay already causes a feeling of discomfort. For Schiller et al (2003), however, it is necessary for this speed to exceed 5.14 m/s.

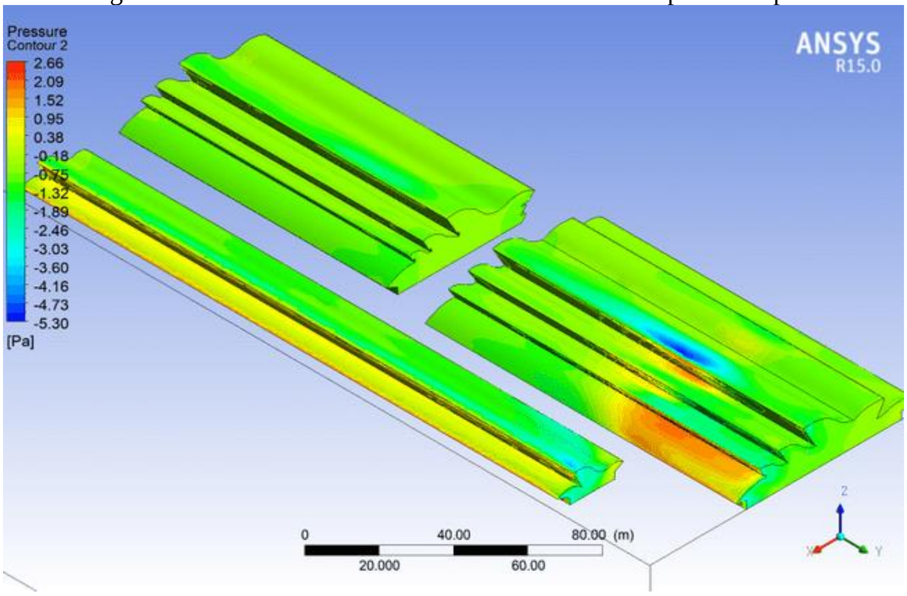
Table 2: Effects of Wind on Man

Escala Beaufort		Velocidade do Ar (m/s)	Efeito sobre o Homem	
Código / Descrição	Intensidade (nós)		EVANS; SCHILLER, 1994 apud LUKIANTCHUKI, 2010	OLGYAY, 1998 apud LUKIANTCHUKI, 2010
0 - Calmaria	<1	< 0,54	Sem sensação de resfriamento	< 0,25 Despercebido 0,25 – 0,50 Agradável
1 - Bafagem	1 – 3	0,54 – 1,54	Movimento perceptivo para o efeito do resfriamento	0,50 – 1 Agradável, presença sentida 1 – 1,5 De pouco a muito incômodo
2 - Aragem	4 – 6	2,05 – 3,08	Movimento do ar sobre a face	> 1,5 Exige medidas corretivas para manter um alto nível de saúde e eficiência
3 - Fraco	7 – 10	3,60 – 5,14	Movimento do cabelo – se inicia o desconforto	
4 - Moderado	11 – 16	5,65 – 8,23	Desconforto.	
5 - Fresco	17 – 21	8,74 – 10,80	Sensação da força do vento sobre o corpo	
6 - Muito Fresco	22 – 27	11,31 – 13,89	Ruído nas orelhas, dificuldade de caminhar	
7 - Forte	28 – 33	14,40 – 16,97	Inconvenientes para caminhar contra o vento	
8 - Muito Forte	34 – 40	17,49 – 20,57	O movimento contra o vento equivale a um pendente de 1/5	
9 - Duro	41 – 47	21,09 – 24,17	Perda de equilíbrio das pessoas	
10 - Muito Duro	48 – 55	24,69 – 28,29	Movimento quase que impossível	
11 - Tempestuoso	56 – 63	28,80 – 32,41	Ocasiona danos gerais	
12 - Furacão	> 63	> 32,41	Extensos danos a zonas edificadas	

Source: Data taken from MARINHA DO BRASIL, 2021 and LUKIANTCHUKI, 2010

Finally, we have the result of the pressures on the facades. From this result, the program's "dropper" tool was used, to precisely pick up the pressure at the location of the section chosen to analyze the interior ventilation.

Figure 20: Simulation 1 Pressure in the Sarah Rio Hospital Complex



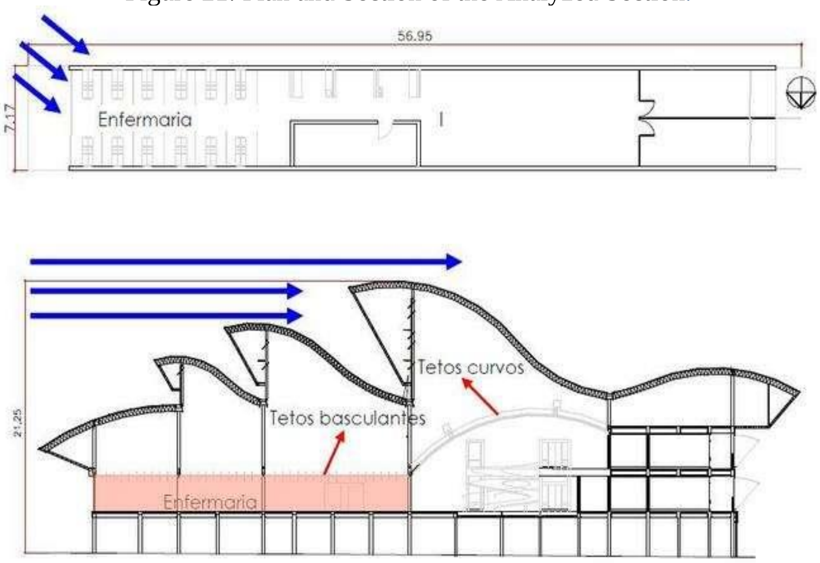
Source: Ansys 15.0 Production Author with support from Nazareth

The points from which the pressures were extracted were at the *sheds*. For each *shed* opening, one pressure was taken, being these: -0.84; -0.81; -0.68; -0.57 on the east facade from the lowest to the highest shed; on the west facade, the pressures were -0.56; -0.57; -0.57 also, from the lowest to the highest opening. These results were used in the second simulation.

3.3.2.3 Internal Ventilation

In simulation 2, a section was made in the complex. The determination of the section size was the actual width of the environment of 7.17 m by 56.95 m which is the total length of the south block, where the infirmary is located, as shown in figure 21.

Figure 21: Plan and Section of the Analyzed Section.



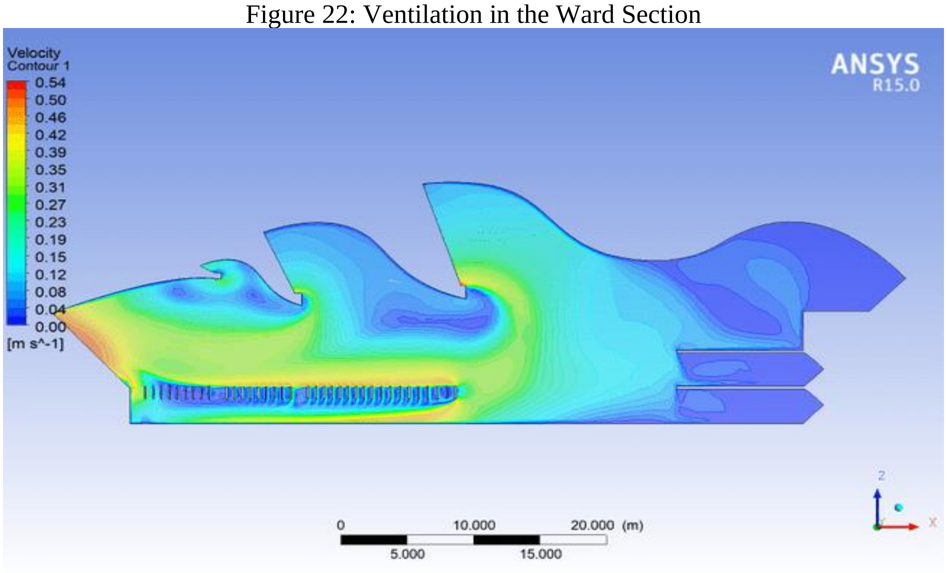
Source: LUKIANTCHUKI,2010 (adapted by the author)

As with the first simulation, for the second simulation, a simplified section was modeled in AutoCad 3D. Only the contour of the complex, and the hinged ceilings present in the infirmary were modeled. For this simulation, the situation in which the sliding ceilings are open was considered. This volumetry was also exported in .sat format to the Ansys-CFD program. Different from the first simulation, the domain of this one was the volume of the section itself, which housed the results of the fluids inside, representing the internal natural ventilation. The input data used for Simulation 2 were those obtained in the first simulation.

The model was organized in the following way: the *sheds on the* east façade, facing windward, were called *openings*, while the leeward *sheds* on the west façade were called *outlets*. The ceilings, floors and walls were called *walls*. In the *sheds*, *the* input data taken from simulation 1 were placed, being: -0.84; -0.81; -0.68; -0.57 on the east façade from the lowest to the highest *shed*, and on the west façade -0.56; -0.57; -0.57 from the lowest to the highest opening. Thus, as in the first simulation, a temperature of 25 °C was adopted for the air, and the turbulence model was also the *k-epsilon*. That said, the simulation was started.

The result of this simulation (figure 22) shows that the natural ventilation enters through the *sheds*, and its speed increases as the air goes down. Another factor that can be analyzed in this result is that the wind, unlike expected, returns to the *sheds* from where it entered. Which allows the conclusion that given the input factors applied in Ansys for the simulation, it is necessary that the external wind, as well as its pressure should be much higher to promote a cross-ventilation flow inside the hospital, causing the *sheds*, facing east, to behave only as wind input and not input and output. It is possible to say that the *sheds*, as modifiers of the wind course, thanks to their shape, force the wind downwards, and that at a certain moment this ventilation becomes stronger, as can be observed in the area near the tilting ceilings.

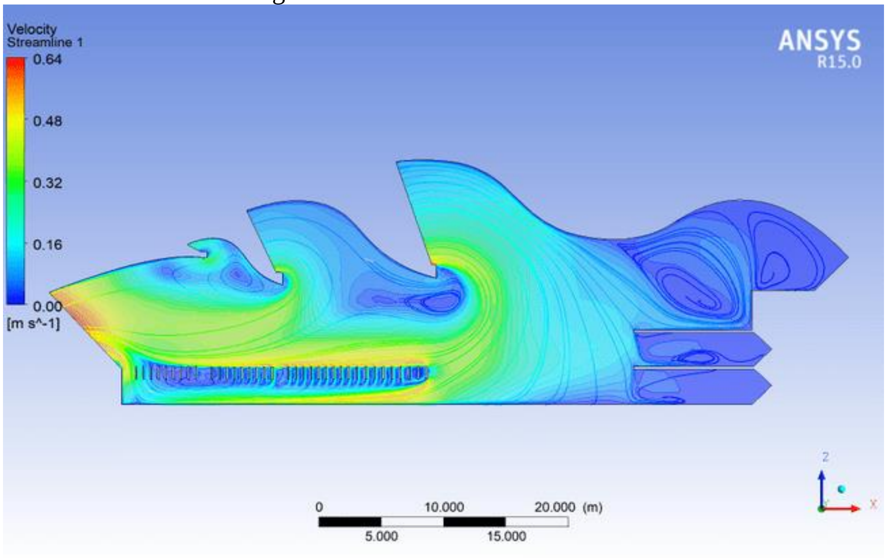
Figure 22: Ventilation in the Ward Section



Source: Ansys 15.0 Author's production with Nazareth support

The simulation also allows us to observe the turbulence effect (figure 23), which occurs in some points of the section, with greater occurrence in the west-facing part of the building. Another interesting fact to observe is that at the leeward side the natural ventilation is minimal, and thus not sufficient for air renewal and thermal comfort, which proves the need for forced ventilation, on days when natural ventilation is not present in this region. A fact that the architect Lelé masterfully developed and solved. In addition to air conditioning, for the days when none of the aforementioned ventilation was sufficient to maintain comfort.

Figure 23: Turbulence in the section



Source: Ansys 15.0 Author's production with Nazareth support

If we get closer to the infirmary area, it is possible to analyze in more detail the action of the winds in this place (figure 23). Thus, inside the infirmary, an area that needs good ventilation for the salubriousness of the air, the ventilation in some points exceeds 0.42 m/s, but most of the time the speed is between 0.15m/s and 0.39m/s near the floor. The 0.4m/s ventilation may be a higher speed for some architectural typologies, however, in hospital areas, this allows for air renewal and quality. The ceilings, as can be seen, end up being minimizers of wind velocity, since the air that passes through the ceilings reaches the patients with a lower speed. The wind that arrives without passing through any barrier has a higher speed when close to the floor, and decreases as it flows eastward.

When it comes to cross-infection, the fact that the air coming from the windward *sheds*, does not flow to the leeward exit, but rather, exits through the same side where it entered, can be said to be an advantageous situation. Since the air passing through the ward can be contaminated and instead of flowing throughout the hospital, it is taken to the outside, without carrying contaminants to other environments, since there are no doors in the ward, which would lead this contaminated air to be dissipated much more easily throughout the various sectors of the complex.

The wind inside the infirmary, besides providing the removal of impurities, also affects the comfort of patients and nurses, to evaluate such comfort the RDC nº 50/2002 points as standard the NBR 16401- 3 (ABNT, 2008) - Air conditioning installations - Central and Unitary Systems -, which in turn presents some minimum parameters that indicate comfort conditions regarding the wind speed. In summer, at a temperature between 22.5°C and 25.5°C and considering a 0.5 clo clothing, the ideal speed would be 0.20 m/s, already in winter with a temperature between 21°C and 23.5°C with a 0.9 clo clothing, the speed would be 0.15m/s, being this standard.

Having said this, it is possible to conclude that, at the moment of simulation 2, the users would be experiencing a sensation of comfort. Since for the simulation an external temperature of 25°C was considered, and the internal air speed had a result between 0.15m/s and 0.39m/s, these values, according to the NBR 16401- 3 standard (2008), are considered comfort parameters.

The results, which these simulations show, provide an understanding of how air and, consequently, natural ventilation behave inside the Sarah Rio Infirmary and its effects on the user. With them, it is also possible to observe how Lelé's strategies are efficient for the promotion of comfort and well-being within his projects, in addition to the effective applicability of bioclimatic strategies proposed by norms and zoning.

4 FINAL CONSIDERATIONS

With this study, it was possible to conclude that architecture is directly linked to the health and well-being of users, especially in hospital areas. In these spaces, the implementation, the openings, the air volume, and the ventilation systems define the quality of the internal air. In these environments, air renewal has a very high degree of importance since it can avoid contamination by fungi, bacteria and viruses.

The sectorization of hospital areas is directly associated with the type of treatment provided, and each of these may require different internal air treatment, such as surgical and administrative sectors. In the case of the Rede Sarah hospital in Rio de Janeiro, even though it focuses on locomotor diseases, its design, in the context of air renewal, is internationally recognized, because the architect João Filgueiras Lima made use of several solutions applying bioclimatic concepts, including natural ventilation, natural lighting, and the use of low environmental impact materials, for example.

Another point raised in this work is that, through the results obtained, it is observed the importance of the architectural design as in the Sarah Rio hospital, where it sought ways to bring the renewed natural air next to the patient, these strategies should be studied and valued. In the infirmary, the architect applied hybrid ventilation, associating mechanical and natural ventilation with an air outlet at bed height, as well as the possibility of improving the quality of the internal air by closing and opening the ceiling, minimizing the amount of accumulated CO_2, renewing the air and bringing comfort.

It can be observed that the simulation results cannot reach the totality of the reality existing on the site, since there is a base defined by the input data and internal bases of the programs. Therefore, there is a simplification in the modeling of reality regarding the number of parameters that exist in the project of the building under study. The analysis concluded that the project greatly reduces discomfort throughout the year, due to the bioclimatic strategies.

New technologies applied to air conditioning systems, with monitoring of fungi, bacteria, and viruses will expand future research in the context of indoor air quality in monitoring the need for filter replacement and maintenance, minimizing diseases in the hospital environment.

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