Winds in Multi-Family Housing Buildings

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Abstract

Although there is progress regarding high-rise residential buildings, there is a need to know the pathologies caused by the absence of a bioclimatic design or a lack of knowledge regarding bioclimatic architecture, characteristics of the materials, simulation context and passive and active sustainability strategies that can be applied. The purpose of the present study was to apply a psychometric design for design techniques applied to housing complexes, the case study made up of 300 high-rise housing or horizontal property buildings built and inhabited to evaluate the comfort of users by calculating the sustainable characteristics of the materials and bioclimatic simulation using the design builder software. The results show that according to the calculation in the residential complex, a wind shadow is produced on the other buildings in the city of more than 800 meters (Z2), that is, it protects them from the wind or prevents other buildings from being ventilated. It is concluded that climate change, by affecting our environment, affects our cities and it is necessary to link new design and construction strategies.

Keywords: winds, buildings, sustainable development.

Introduction

The influence of winds on multifamily housing buildings is a critical aspect of architectural design and urban planning. Winds, as one of the most dynamic and variable natural forces, play a fundamental role in the structural stability, energy efficiency and quality of life of residents in multifamily buildings. The increasingly frequent heat waves triggered by climate change focus attention on the important relationship between land cover and temperature, particularly in urban areas with a greater presence of artificial surfaces, often asphalted and built in concrete or with fewer planted areas. (Battisti, 2020). This is why in many countries new regulations have been issued to take advantage of the winds in new constructions. The building sector is an activity where the potential for saving energy is important and Morocco is now placing the housing sector and energy efficiency and renewable energies among the national priorities in order to combine security of supply and reduction of dependence on energy, environmental preservation, reduction of energy consumption and thermal comfort. (Harrouni et al., 2018)

Winds in multifamily housing buildings are an important factor to consider in the design, construction and use of this type of structures. Ventilation systems are absolutely necessary to ensure adequate levels of indoor air renewal. In Portugal, multifamily buildings use natural, mechanical or mixed ventilation systems. (Pinto et al., 2017). Furthermore, in a world that is constantly changing and with accelerated urban growth, understanding and analyzing the effects of wind on this type of buildings becomes essential to guarantee their long-term sustainability and safety. For this reason, ventilation is of great importance to define hygrothermal comfort conditions and indoor air quality in buildings. Since there are multiple options and a variety of properties related to humidity and temperature, Passive building designers and consultants are encouraged to use hygrothermal simulation for assemblies with which they have no experience or in climates that are unfamiliar to them.

With multiple choices and varied hygrothermal properties, new passive house designers and consultants are encouraged to use hygrothermal simulation for assemblies they are either not experienced with and/or climates they are not experienced in. (Asdrubali and Desideri, 2019). It is absolutely necessary both to remove pollutants and humidity produced by the use of buildings and to guarantee the oxygen levels necessary for human metabolism and for the operation of combustion devices. Changes have been made to improve thermal performance in building structures (the envelope), the amount of energy required to maintain an adequate indoor temperature has decreased significantly. This is because the building envelope is more effective at retaining the desired temperature. For the management of the life cycle of thermal comfort, it will be possible to have a service performance per element involved and to define its environmental and economic costs. (Marín Salgado, 2012). A major consideration in architecture has always been the need to design for the climate. Bioclimatic analysis should be considered in relation to other environmental factors as an indicator of thermal comfort in buildings. (Dorcas Mobolade & Pourvahidi, 2020). All of the above confirms that traditional architecture has always had a vernacular architectural design style with an organic development, adapting to the climatic, geographical, cultural and social conditions of its environment, using locally available construction materials and techniques, but now modern bioclimatic strategies are being applied to create buildings that are highly energy efficient and environmentally friendly. Vernacular architecture and its responses to natural factors through architectural patterns are recognized as expressions of bioclimatic principles. (Rajkovi´c et al., 2022). Enclosed blocks, plots with little façade space and low building heights can be discerned in vernacular urban design. (Montalbán Pozas & Serrano. 2022). Respect to winds in multifamily housing buildings, cross ventilation is also applied to design strategies that allow the flow of fresh air through a living space by taking advantage of pressure and temperature differences between the outside and inside of a building, this ends up improving indoor air quality, reducing heat and humidity buildup. The Cross ventilation (CV) is planned for operation during night-time when the office space is unoccupied and when are theoretically the highest cooling capacities related to local wind speeds from one side, and from the other, when are primarily lower nocturnal air temperatures ranges. (Pesic and Muros Alcojor, 2022).

Over the years, human comfort has been a key priority in the process of designing spaces. Before mechanical solutions were available, attempts to achieve this goal were naturally passive. Today, even with advances in mechanical solutions, passive methods remain preferred due to the increasing need for sustainable solutions due to current global environmental concerns. Climate parameters such as temperature, daylight, wind or humidity are duly analysed to provide optimal indoor conditions and considerable energy savings. (Widera, 2021). Passive thermal conditioning systems for homes are presented as a valid alternative to achieve hygrothermal comfort, particularly for those people who cannot access the use of systems that use conventional energy, due to their high cost. (Cúnsulo et al., 2019). The energy savings that would be achieved by applying the sustainable architecture approach, especially in the planning and construction of social housing, would have a significant impact on local energy demand. This is because the resulting energy savings could be redirected towards production activities, which would increase the availability of energy resources for other purposes. Implementing sustainable practices in home construction would not only benefit communities by reducing energy costs, but it would also have a positive impact on the fight against climate change by reducing greenhouse gas emissions. Climate change is accelerating due to greenhouse gases produced mainly by the high energy consumption of non-renewable resources, which damages the environment. (Salameh & Touqan, 2022).

Historically, common passive solutions include shading devices, ventilation techniques, and and cooling methods and passive heating. One of the most common cooling and ventilation techniques is the wind tower, also known as a wind catcher. Thermal performance is an important aspect of intelligent and sustainable buildings. Research calls for sustainable building envelops to protect buildings from unpredictable weather conditions and maintaining green environment. (Binyaseen, 2022). The study of winds in multifamily housing buildings is essential to guarantee the safety, comfort and efficiency of these living spaces. This research focuses on how winds affect the structural stability, indoor air quality and energy consumption of residential buildings. In relation to the above, government policies must be generated that promote the sustainable buildings creation, starting with public buildings and multi-family residential buildings. The government's green building policy has mainly focused on public buildings and multi-family residential buildings, and it has authorized green building certification systems to further promote building energy efficiency. (Lee et al., 2021).

Building designs based on an optimized built environment using external shading systems seek to solve problems through simulation of building performance and qualitative analysis. Building designs based on a built environment optimized by external shading systems aim to solve problems through building performance simulation and qualitative analysis. (Li et al., 2021). So considering the challenges and opportunities that arise from addressing the winds in this context, promoting the improvement of quality of life in urban communities and through an interdisciplinary perspective, the aim is to comprehensively address the implications of winds on the habitability and sustainability of multifamily buildings. Different climate zones have introduced variations of building designs, which have affected building efficiency. Buildings are typically constructed in cold environment regions to use internal heat and to minimize heat loss. (Elshafei et al., 2021). In cities with cold climates, buildings are designed to take advantage of all the internal heat by retaining the heat that is generated internally, but in cities with warm climates, buildings are designed that can avoid internal heat, often by introducing cold air. Finally, this research project focuses on examining wind patterns in detail, its impact on the architecture of multifamily housing and possible design and mitigation strategies to optimize the habitability and efficiency of these buildings. Through a multidisciplinary analysis ranging from structural engineering and climatology to architectural design, this study seeks to shed light on how winds affect the form, functionality and performance of multifamily buildings, and how design and construction professionals can integrate this knowledge into their practices to create more sustainable and livable urban communities.

Methodology

The proposed methodology to implement bioclimatic design and sustainability strategies in high-rise residential buildings is simulation, for this reason, psychometric design was applied for design techniques applied to housing complexes, the case study made up of 300 high-rise housing or horizontal property buildings built and inhabited to evaluate their comfort for users by calculating the sustainable characteristics of the materials and bioclimatic simulation. According to Guasch Petit et al., 2002, simulation is a valuable tool to understand and improve the efficiency of processes and systems and this work likely explores how these approaches can be applied in the field of logistics and manufacturing. It was structured in the following steps:

Psychometric Analysis and Energy Simulation: In this initial stage, psychometric design techniques were applied, using simulation software such as DesignBuilder to model and analyze the energy performance of the building.

User Comfort Assessment: A detailed assessment of user comfort in high-rise residential buildings was carried out. Subsequently, calculations of the sustainable characteristics of the materials and bioclimatic simulations were carried out to better understand the indoor environment.

Design and Optimization of Building Performance: Using the results of the previous simulations, the building design and optimization process was carried out. Then we sought to improve the energy efficiency and thermal comfort of the building based on the information collected.

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Measurement of Key Factors: At this stage, wind protection and ventilation were measured and evaluated, taking into account that these factors are fundamental for the habitability and energy performance of the building.

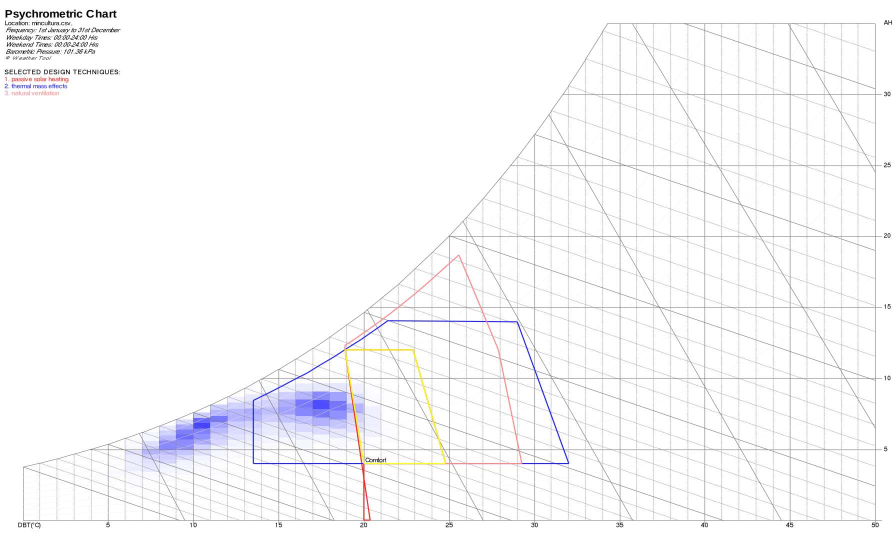
Application of Psychometric Design in Housing Complexes: The methodology is applied to a specific case study, a housing complex composed of 300 high-rise housing properties or horizontal property. User comfort was evaluated in this context, again using calculations of sustainable material characteristics and bioclimatic simulations.

This methodology is a comprehensive approach that combines design techniques, performance evaluation and optimization to obtain information about high-rise residential buildings that are energy efficient, comfortable for their inhabitants and respectful of the environment.

Results

Next, the three IDEAM stations where the wind data were taken, in such a way that their position was triangulated with respect to the three buildings that make up the Torres Blancas residential complex. Information was taken from four ideam stations for meteorological measurements, measuring altitude, unit and difference, ideam stations venado station with an altitude of 2725 units in masl and a difference of +81; ideam stations Carrera 10 station with an altitude of 2705 units in masl and a difference of +61; stations of the ideam residential complex Torres Blancas with an altitude of 2644 units in masl and a difference of 0; ideam stations, airport station with an altitude of 2547 units in masl and a difference of -97; Torres Blancas housing complex is located above the airport station at 97 meters and below the Carrera 10 station at 61 meters and the Venado station below at 81 meters. Next, in the psychometric table you can see the relative humidity scale on the right and the ambient temperature scale at the bottom, the comfort zone that can be established for the resident of the Torres Blancas housing complex and according to the environmental conditions of the city of Bogotá and according to their cultural habits and clothing, it is between 20° and 25° C, (see blue line box) when the building is analyzed in the graph, some blue boxes leave the comfort area, it shows that in the blue boxes that are on the outside they are less than 20° C, and in some seasons they will be between 5° and 10° c.

Figure1. Psychometric for design techniques for housing complexes.



One of the strategies to achieve a good level of comfort would be to increase the mass of the walls, so that there is heat absorption and that there are no internal temperature losses. The red part shows that the sun is not going to heat up much because of the height at which the building (Torres Blancas) are located and it will not be a strategy that will greatly benefit the project in this point in the city. It can be concluded that 95% of the year the temperature

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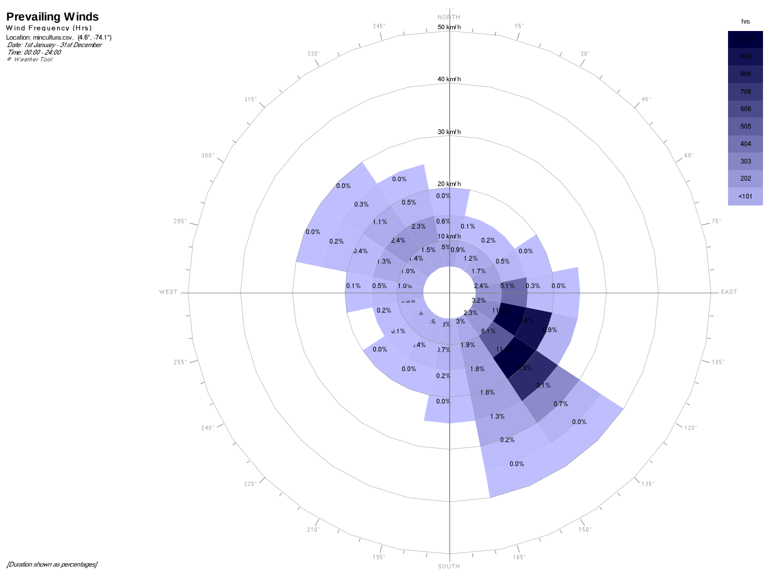
inside the White Towers is outside the comfort range, creating humidity and mold problems, as is evident in reality, which is why making use of the winds is very useful.

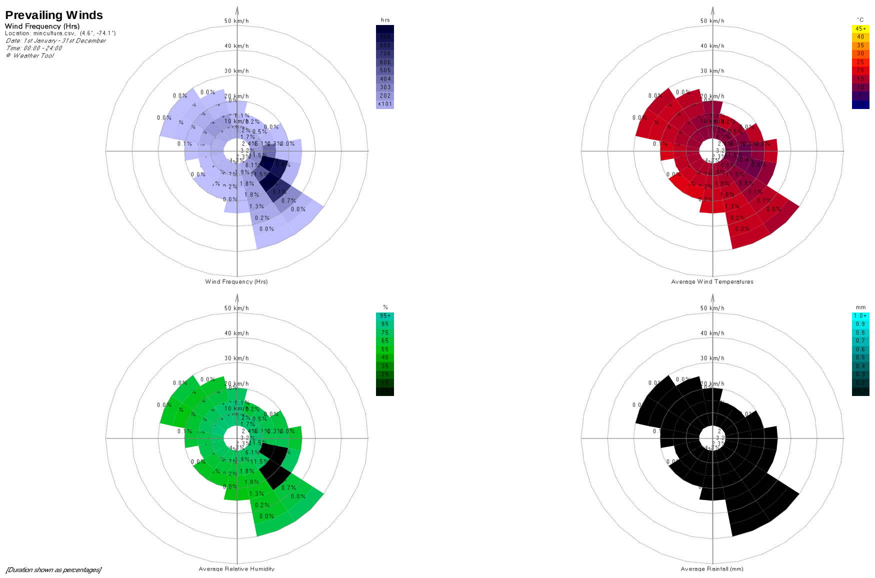
Figure 2. Compass rose for the residential complex



Note. Wind rose measuring speed in km/h, direction and intensity.

In the previous figure "The Rose of the Winds", the prevailing winds from the south-eastern side are indicated in dark blue with speeds between 20 and 40 km/h, corresponds to the winds that come down from the eastern hills with their respective humidity which is added to the cold that already exists inside the apartments of the Torres Blancas Housing Complex located in the city of Bogotá, Colombia.

Figure 3.Measurement of winds, temperature, humidity and precipitation.



Note. Prevailing winds taking into account speed (purple color), temperature (red color), relative humidity (green color) and precipitation (black color).

Here the prevailing wind is always observed to be from the south-east direction, that is, the wind comes down or bounces off the eastern hills, its speed, frequency, temperature and humidity vary. Next, calculation of the wind shadow for the Torres Blancas Residential Complex, according to the dimension data of each building in this case the three are the same height of 75 meters, width of 24 meters and length of 26 meters, and according to the Fuentes Víctor wind shadow calculation table and with the average wind speed in m/sec. that the maximum pressure height is 50 meters.

The result of the maximum shadow over the city is 818.38 meters. The generation of turbulence or negative pressure on the affected facade is also observed. To calculate the wind shadow for Torres Blancas building, the dimensions of the building are taken into account, that is height=H giving a value of 75 m; width W=24m; length L=26 m; Calculation of coefficients Bs 24m, is the smallest dimension between H and W, where BL= 75m is the largest dimension between H and W, R=34,96, that is, the Z1 Wind Shadow, where Hc=7,69 m; Xc=17,48 m; Lc=31,46 m; Z4Lr 34,96 m; Z2=818,38 m; where the wind shadow relation Z2/H 10,91; Calculation point x 40m; Z3=10,23m.

The calculation point x is measured from the upper vertex of the Torres Blancas facade, the calculated height Z3 is measured from the roof level of the building at distance x and the maximum wind pressure on the Torres Blancas facade: where the Density of air at 0 °C; 1,29kg/m3; See Wind rose: Wind speed v 6,91m/s; Maximum fluid 11,11 m/s; Dynamic pressure pw 30,80 Pa; Minimum fluid 2,7 m/s; maximum pressure head + hmax 50,00m; two thirds of H 13,81; with an Average of 6,905 m/s. According to the dimension data of each building, in this case all three are the same height of 75 meters, width of 24 meters and length of 26 meters, and according to the Fuentes Víctor wind shadow calculation table, and with the average wind speed in m/sec. that the maximum pressure height is 50 meters. The result of the maximum shadow over the city is 818,38 meters. The generation of turbulence or negative pressure on the affected facade is also observed.

Conclusions

In the psychometric, the intention to promote the phenomenon of black mold inside the residential complex is visualized, if the windows remain closed and the users do not open them, they generate insufficient ventilation, which means that humidity may form in the windows, doors, walls, floor, ceilings, in places inside the apartments where the air does not move because there is not enough wind to remove it, this generation of mold is a fungus called Stachybotrys chartarum, due to the environment is prone to such as Cladosporium, Penicillium, Alternaria and Aspergillus, in the spaces of the apartments that do not receive natural lighting or sunlight, the phenomenon increases, giving the conditions to spread, contaminating the building materials and their furnishings.

This generation of black mold releases mycotoxins upon direct contact, causing health problems for people who remove it or are near it, black mold enters the lungs and affects different organs of the human body depending on the concentration and physiological conditions such as respiratory difficulties, allergies, including death by poisoning. These affect pets by causing aflatoxins and ochratoxins. Therefore, it is recommended to ventilate and allow sunlight to enter, materials must be waterproofed and maintain an ambient temperature in comfortable conditions according to the number of people who live there and the climate where the property is located.

According to calculations in the Residential Complex, it is observed that it produces a shadow from the wind on the other buildings in the city, that is, it protects from the wind or prevents other buildings from being ventilated, the floors that withstand the greatest wind pressure are fifty meters high, which corresponds to the apartments located on floors greater than sixteen, where there is turbulence on the facade behind the one that receives the wind, there is greater pressure on the roof that receives the wind. Climate change affects the environment and the city, therefore, needs new design and construction strategies, giving priority to the production of alternative energy, water consumption, comfort temperature, isolating noise, promoting pleasant smells; Currently, buildings are considered heat islands due to the lack of sustainable design elements; Therefore, it is necessary to consider the urban space between each building and air currents through wind shadows.

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