Modelling And Simulation of Building Performance in Relation to Wind Flow Pattern of Natural Ventilation System.

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Abstract

Any society's well-being and ability to endure depend critically on the quality of its built environment. Users of buildings are closely integrated with building performance; this is so because they are the ones that gauge the performance levels of the building. Building users will be drawn to a high-quality, cozy, safe, and healthy building, which will impact the supply and demand of building stock. This study used a computational fluid dynamics (CFD) simulation to assess the wind pattern relations with urban planning tool as the process for evaluating the relationship between wind patterns and urban design. Three scenarios were compared based on the wind velocity magnitude (480-000 cm/s) obtained from the CFD simulations. The first and second scenarios agree with one another, with the wind velocity magnitude ranging from 0-160 cm/s (@ 1/1.6m/s) around the wall corners and bed level. This suggests that the desired air velocity surrounding the building will maximize the comfort levels of the building's occupants by allowing for good natural ventilation and adequate aeration both inside and outside the building. The desired air velocity outside the window will allow for hot, undesirable air in the third scenario, where the wind velocity magnitude ranges from 300 to 360 cm/s (@ 3/ 3.6 m/s) around the window level. The air flow inside the building can be seen as fairly okay, allowing for a certain amount of aeration within the building. As a result, the study comes to the conclusion that ventilation and building layout are strongly related.

Keywords: Building performance, Ventilation, Spatial configuration, Computational fluid dynamics (CFD), Wind Velocity.

INTRODUCTION

The primary objective of any building is to give its occupants safety, comfort, and shelter. To accomplish this, buildings are therefore planned, designed, constructed, and managed in compliance with particular standards and regulations, under the supervision of experts and government agencies (Khalil, 2009; Meir, 2009). The building industry has developed innovative ways to lower Green House Gas emissions as a result of the negative effects of climate change and rising public environmental awareness (Erten, 2009; Assefa, 2005). Buildings' requirements for air conditioning, ventilation, and heating account for a large portion of the global energy consumption (Grygierek & Ferdyn-Grygierek, 2018).

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According to studies, buildings account for more than 40% of all energy use (Moran, Goggins, & Hajdukiewicz, 2017; Allouhi, et al., 2015). Every building has unique characteristics based on the variations in the building's internal and external environments. There have been attempts to lower building energy demands by minimizing envelope losses, usually by enhancing insulation. Ventilation is a building technology used to regulate indoor air quality and establish a comfortable temperature.

The concentration of chemical species in the air, air temperature, relative humidity, and air speed are some of these parameters. Having the right instruments to forecast building ventilation performance is crucial for controlling indoor air quality (Chen, 2009). The envelope experiences the largest energy losses because of inadequate ventilation, infiltration, and insulation. Furthermore, research has demonstrated that air leak losses can result in issues with reduced thermal comfort as well as a decline in ventilation systems (Jesús, et al., 2018).

Building performance includes notions of use and effect on human performance, because performance is assessed in terms of how buildings and building system affect the comfort, effectiveness and well being of building users Because performance is measured in terms of how buildings and building systems affect occupant comfort, building performance takes into account concepts of use and effect on human performance (Preiser, 2002).

effectiveness and wellbeing of building users (Preiser, 2002). To assess how well a building is behaving overall and in the long term. It is important both in an inter building and intra building sense. Becker (1996) All buildings require, throughout their life, a level of performance and a standard of management that can provide and sustain conditions suitable for the well-being of their users. The approaches to building performance consist of built ability; flexibility; maintainability; adaptability; and marketability.

To evaluate the general and long-term behavior of a building. It is significant from both an intra- and inter-building perspective. According to Becker (1996) throughout their existence, all buildings must operate at a level and adhere to a management standard that can create and maintain environments that are conducive to the wellbeing of their occupants. The strategies for improving performance are marketability, flexibility, maintainability, adaptability, and built environment. Bluyssen (2009) highlighted that the features for healthy buildings are free from hazardous materials and provide healthy and comfort environment for the building users throughout the building lifecycle. Therefore, this will influence both the image and value of a building.

The main scope of building performance is to assure a quality assets that is able to integrate with user perceptions to achieve a desired lead of customer satisfaction. McDougall et al (2002) mentioned that building performance has a strong relationship with building design and building occupants.

In general, for a building to offer a safe and healthy environment, it must perform to a certain standard. Bluyssen (2009) emphasized that the characteristics of healthy buildings are devoid of dangerous materials and offer a comfortable and healthy environment for building occupants throughout the building's lifecycle. As a result, this will affect a building's value and reputation. Ensuring high-quality assets that can be integrated with user perceptions to achieve the desired lead of customer satisfaction is the primary purpose of building performance. McDougall et al (2002) stated that there is a strong correlation between building design and building occupants and building performance. The process of evaluating a building's performance is called building performance evaluation (BPE). BPE can be used to verify that a building's actual performance aligns with its intended performance (Hub, 2023). BPE can cover many aspects, including:

Fabric thermal performance and airtightness, Heating and ventilation services, Energy use, Indoor air quality, Overheating, Householder experience. Although a lot of researches has been carried to assess building performance, they all focused more on the decision-making process throughout the building process than providing a comfortable environment for building occupants (Preiser W. a., 2005; Preiser, 2005). There is dearth in the study to assess building performance in relation to the building components (windows, bed level and wall corners), this paper intends to fill this gap. Throughout the building life cycle, including design, construction, operation, and maintenance, computer-aided building performance simulation has been utilized as an effective means of boosting building energy efficiency (Xiao, 2020).

STUDY AREA

Mandate Housing Estate is located New Yidi Rd, Ilorin, Nigeria, Kwara. The estates were built as a housing policy scheme aimed at increasing home ownership among low income earners. The estate consists of 4 bed room flats, 3 bedroom flats, 2 bedroom flats and Mini flats as presented in the chart below (Olowoleru, Familua, & Abdulkareem, 2020).

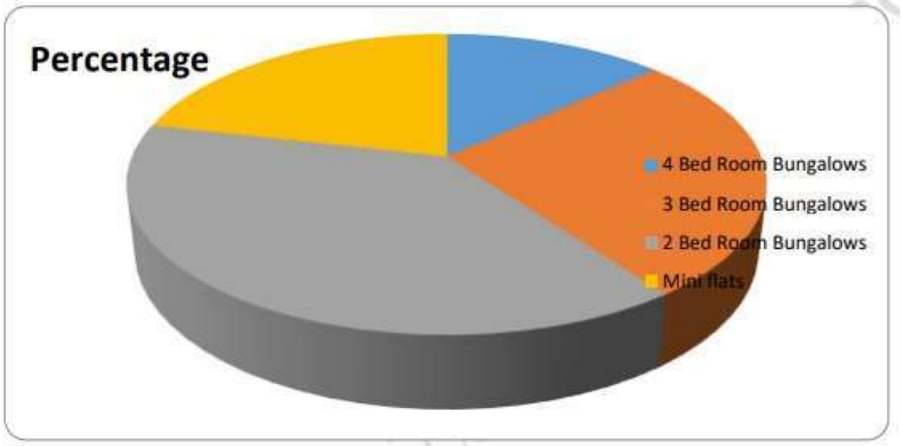


Figure 1: percentage of allotted number of blocks in mandate estate Ilorin. Source: Olowoleru, Familua, & Abdulkareem, (2020)

LITERATURE REVIEW

Our lifestyle has undergone significant change over the ages. To generate the food, energy, mobility, and other needs for modern living, we are now more reliant on industry and machinery. The quality of the air and our planet have been greatly impacted by this. In addition to producing pollutants and particulate matter, these processes also release other gases, such as carbon dioxide (CO2), which is increasing the average global temperature outside a building's interior is known as ventilation. By doing this, the stale air is replaced with fresh, oxygenated air, removing all of the pollutants that may have accumulated during occupancy, including CO2, moisture, odors, dust, aerosols, bacteria, allergies, and airborne viruses. This airflow has many important benefits that the building and its occupants can benefit from (Kingspan, 2021). Figure 2 below shows the Everyday sources of contaminants in the air.

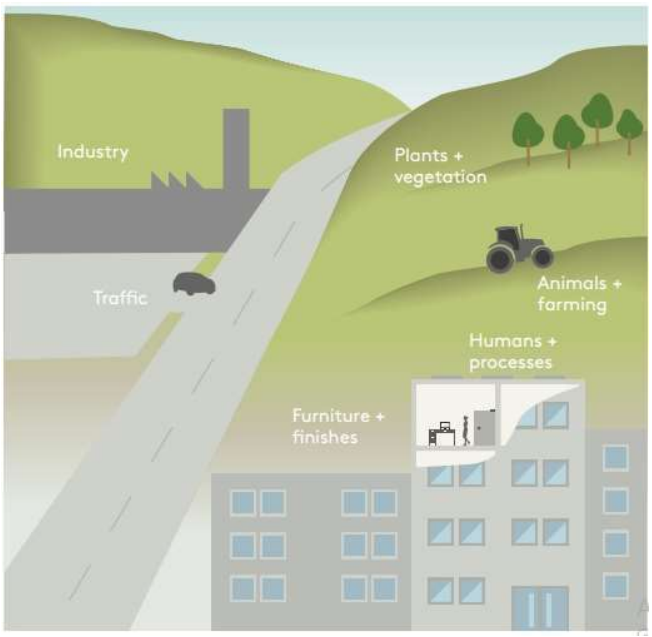


Figure 2: contaminants in the air. source; Kingspan, (2021)

Benefits for Occupants

Health

Since 90% of people's lives are spent indoors, it makes sense that the air we breathe in these enclosed spaces has a big impact on our health. Several scientific studies show that indoor air quality (IAQ) and human health are closely related.

Well-being and productivity

Naturally, health is more than just physical well-being. Many international studies in a range of building types and with a diverse range of occupants have shown that good indoor air quality (IAQ) is also beneficial for our mental health. In general, ventilation techniques that increase thermal comfort and give us a direct line of sight to the outside environment can positively impact our emotional wellbeing, and the feel of a breeze brushing against our skin can be soothing.

Considerations when choosing a ventilation system:

While creating a ventilation strategy may appear simple on paper, putting a successful and efficient system into place can be quite challenging and require a careful assessment of a number of project-specific factors. The people designing the system need to have a thorough understanding of the building the system will be used on, the relevant standards, and the available solutions.

Building specifics:

Building Location
Assessing the surrounding environment and local air quality during the design phase can help in the selection of the most effective ventilation technique. For natural ventilation systems to work, the outside air quality needs to be higher than the interior air quality. If not, using mechanical solutions with air filtration will be necessary to reduce the amount of particulate matter entering the facility. Prevalent weather patterns may also have an impact.

Building Geometry
The volume, form, and organization of the interior space all affect how air flows through a structure. Computational fluid dynamics, or CFD, software can be used to assess how air moves through a space and which ventilation strategies will function best. Understanding this is particularly important when developing a passive system that relies on wind and thermal buoyancy.

Construction
The building's structure might also have an effect on the ventilation requirements. There will always be some level of air infiltration in a building—this is the leaking of air from the outside through cracks caused by construction. While older buildings will have higher rates of infiltration, modern architecture strives for ever-greater airtightness for thermal efficiency. ***Types of ventilation systems***
Mechanical and natural ventilation systems are the two main types. The preference is usually given to naturally occurring ventilation systems, but there are no hard-and-fast rules about which should be used; instead, the needs of each project should be evaluated individually to determine the best course of action. Natural ventilation is taken into account in this paper.

Natural ventilation systems
Natural ventilation is crucial to a passive cooling strategy because air flow through buildings has a significant impact on heat flows and comfort in these spaces (Santamouris & Asimakopoulos 1996). One way to describe the pressure differences that propel air flow through a building is as a result of wind pressure or the stack effect. The temperature-driven differences in density between the inside and outside of the building, as well as the height differences at the inlet and outlet, are what cause the stack effect. When a building is surrounded by wind, the windward side experiences positive pressure, while the leeward side experiences a corresponding negative pressure. Khan et al. (2008) provide an overview of the various designs that promote wind-driven natural ventilation. Many of the reviewed studies make use of natural ventilation numerical modelling techniques.



Figure 3: modes of natural ventilation. source: Khan et al. (2008)

METHODOLOGY

Asfour (2007) acknowledged that the field of predicting airflow rate, air velocity, air temperature, and airflow patterns inside and around buildings, as well as evaluating the micro-scale atmospheric environment surrounding the human body and pedestrian wind environment, are some of the applications of computational fluid dynamics (CFD) in the built environment. This study aims to evaluate the performance of buildings with respect to natural ventilation. Thus, for this study, computer simulation tool (CFD) shall be used, due to its proficiency in its wind assessing wind flow within the built environment and its relatively low-cost. Using sets of parametric models, data on the buildings' air flow performance and the quality of the most important environmental variables—air direction (AD) and air velocity (AV)—on their natural ventilation and air quality in the housing topologies were gathered. Autodesk CFD and the auto-lisp programming language. Four (4) distinct building components were used as variables for the purpose of this study (windows, bed level, wall corners and spatial arrangement) to assess the building performance at the spatial configuration at wall corners, bed level and window level for the building model.

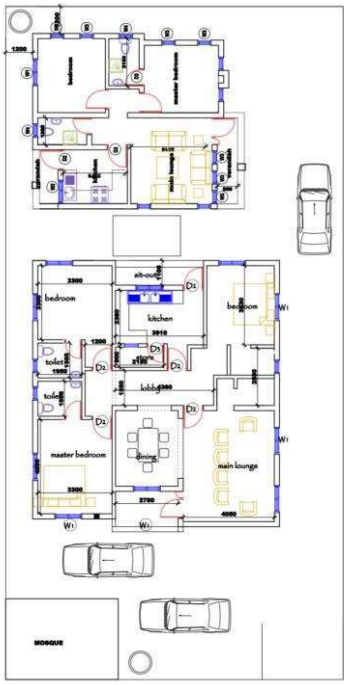


Figure 4: Base case model. source: Authors' work,(2024)

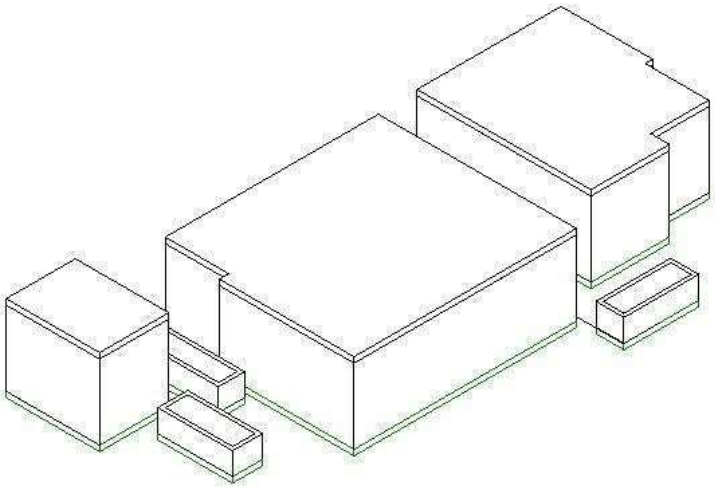


Figure 5: proposed model. source: Authors' work, (2024)

RESULTS

By using parametric iterations, the goal is to compare and link air velocity with occupant comfort levels for air direction and air velocity in relation to natural ventilation and air quality. Three different variables (wall corners, beds level, and window level) were compared and showed the distribution of air flow around the building. The wind velocity magnitude is varied against wind direction in relation to natural ventilation and air quality/comfort levels of the occupants. The results are related to the wind speed and direction at any point of the residential areas. The findings are also concerned with the distance between spatial configuration of wall corners, which is adequate and necessary for equal and proper ventilation for all the houses.

In the first scenario, the model assessed building performance at the spatial configuration of wall corners. From the sectional plan view (plate I), the wind velocity magnitude (480-000cm/s) ranges from 0-160 cm/s (@ 1/1.6m/s) around the wall corners, indicating that the desired air velocity around the building will allow for good natural ventilation and adequate aeration both inside and outside the building, maximizing comfort levels for the building's occupants. Plate II depicts the airflow around the building. Because of the direction of the wind, this airflow would create effective natural ventilation because of the pressure, which might further contribute to a desired level of comfort.

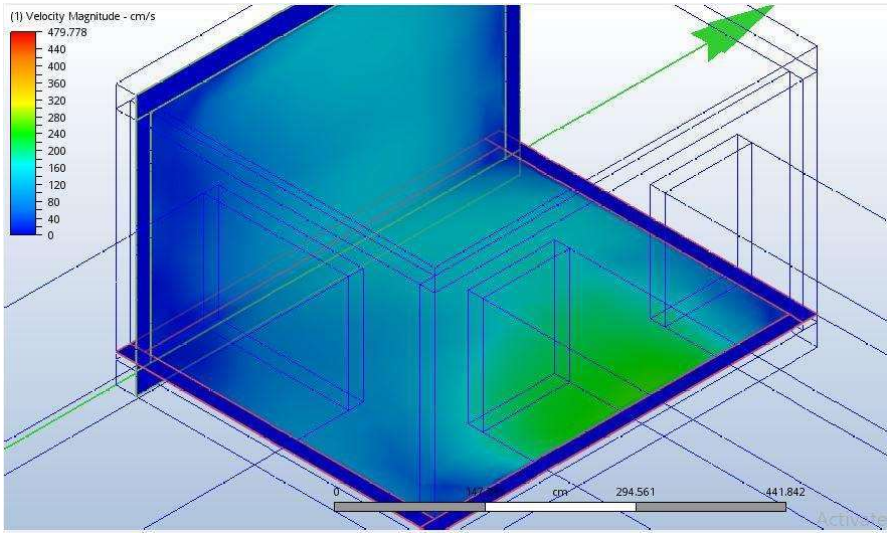


plate 1: wind velocity magnitude and direction for spatial configuration at wall corners. source: Authors' work, (2024).

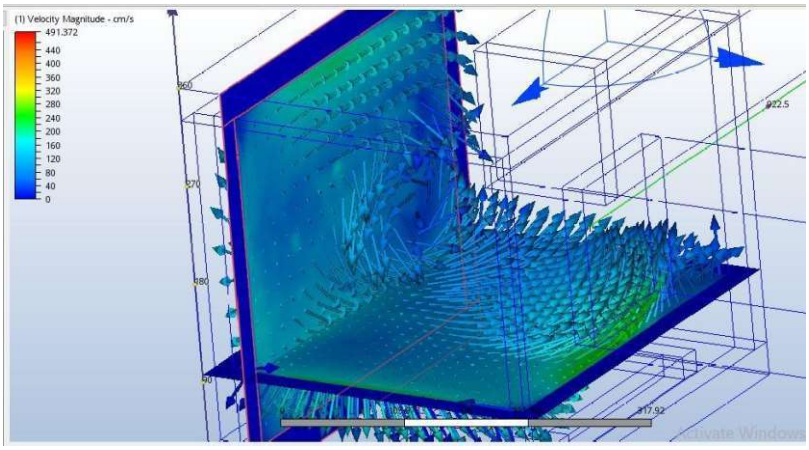


plate 2: Airflow pattern for spatial configuration at wall corner. source: Authors' work, (2024).

In the second scenario, the model assessed building performance at the spatial configuration of beds level. From the sectional plan view (plate III), the wind velocity magnitude (480-000cm/s) ranges from 0-250 cm/s (@ 1/ 2.5 m/s) around the beds level, indicating that the desired air velocity around the building will allow for good natural ventilation and adequate aeration both inside and outside the building, maximizing comfort levels for the building's occupants. Plate IV depicts the airflow around the building. Because of the direction of the wind, this airflow would

create effective natural ventilation because of the pressure, which might further contribute to a desired level of comfort.

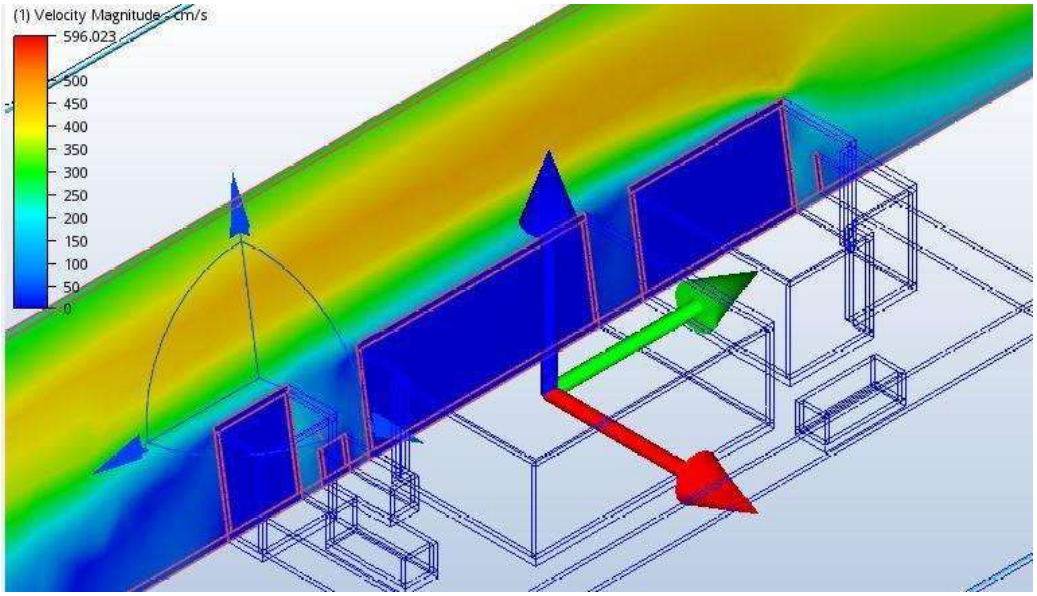


plate III: wind velocity magnitude and direction for spatial configuration at beds level. source: Authors' work, (2024).

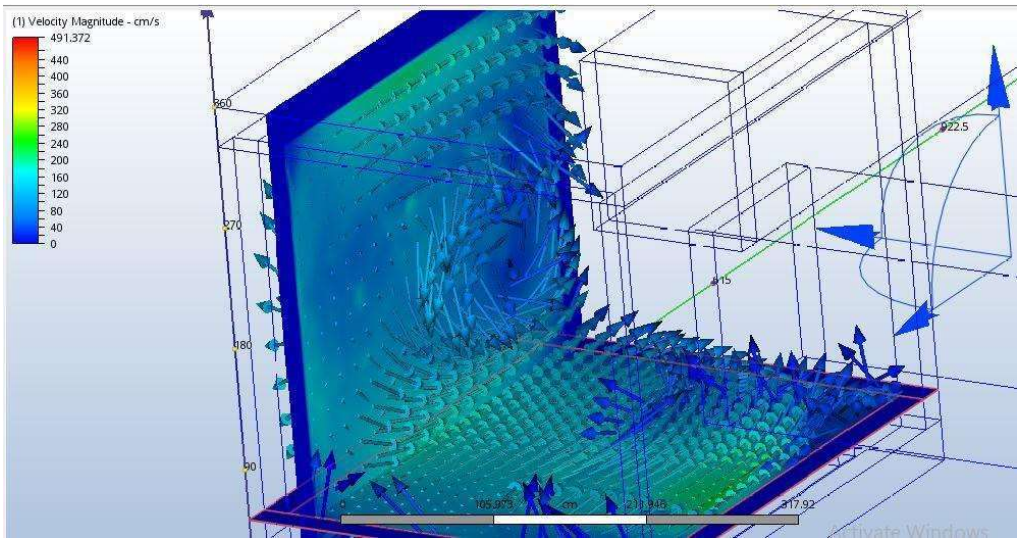


plate IV: Airflow pattern for spatial configuration at beds level. source: Authors' work,(2024).

In the third scenario, the model assessed building performance at the spatial configuration of window level. From the sectional plan view (plate V), the wind velocity magnitude (480-000cm/s) ranges from 300-360 cm/s (@ 3/ 3.6 m/s) around the window level, indicating that the desired air velocity outside the window will allow for hot undesired air and the air flow in the building can be seen as considerably okay allowing for some level of aeration inside the building, Plate IV depicts the airflow around the building. Because of the direction of the wind, this airflow inside the building would cause effective natural ventilation because of the pressure,

which might further contribute to a desired level of comfort. But can be seen that at the airflow around the building has an undesired hot air, which will further lead to discomfort.

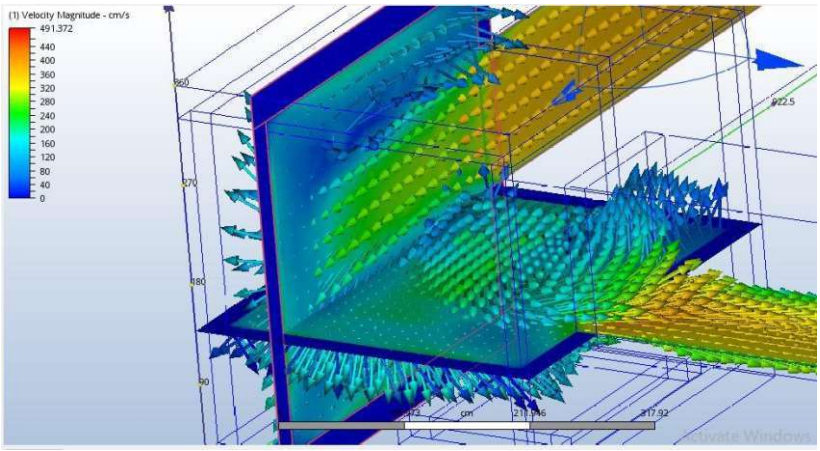


plate V: wind velocity magnitude and direction for spatial configuration at window level. source: Authors' work, (2024).

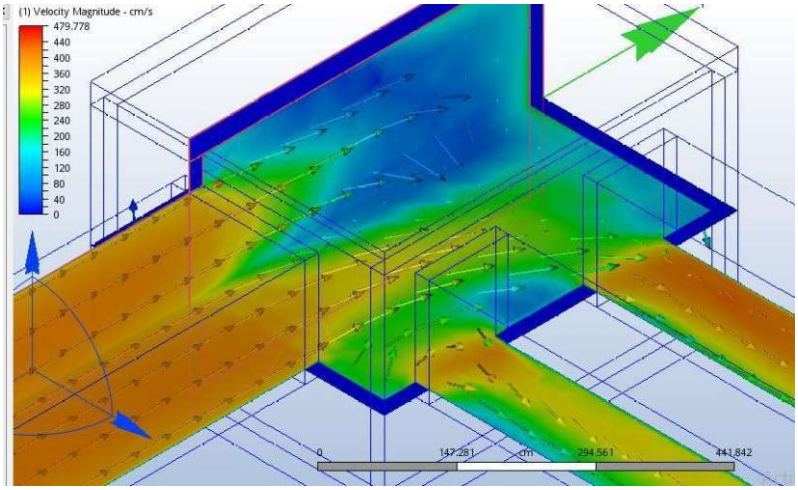


plate VI: Airflow pattern for spatial configuration at beds level (source: Authors' work, 2024).

CONCLUSION AND RECOMMENDATION

In this research, Computational fluid dynamics tool CFD is used to study and analyze the wind pattern. The study aimed to investigate wind pattern and behavior in residential areas to ensure natural ventilation and arrive at guidelines and standards that contribute in planning, urban and architectural design of residential buildings and built environment.

The scenario (spatial configuration at wall corner) showed the greatest potential for causing good natural ventilation and was also the most desirable in terms of occupant comfort, which leads to a sustainable environment; the second scenario also had good and desirable natural ventilation and occupant comfort; the model evaluated building performance at the spatial configuration at three different variables (wall corner, bed level, and window level) and simulated and compared; Because of the wind velocity and airflow around the building, which varied from 3 to 3.6 m/s,

the third scenario had the least amount of comfort and little to no natural ventilation. However, the airflow inside the building provides a moderate level of comfort for the occupants. These factors lead one to the conclusion that ventilation and the spatial arrangement of buildings are closely related. Based on the above conclusions, some of the following recommendations are related to the urban design, planning process and the architectural design of residential areas. When all the houses are of equal height (one storey), the open space must be 30 m wide at least, and separate each four or six rows of houses at the most. Increase the setback width, which are east and west ward to more than 3m so as to reduce the scattered wind that stir dust and dirt. And also reduce the width of the setback which are directed to the north – south, to 3m or less to help increase wind speed. Whenever the distance between the building window level and boundary wall is greater than 2.5 m or more from the north or south side, the wind speed exceeds 0.75 m/s in this area. This means possible and effective natural ventilation for the buildings.

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