ISSN: 3064-9846
Research Article

Journal of Agricultural, Earth and Environmental Sciences

Natural Ventilation Strategies for Highrise Buildings in the Mediterranean Region

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Submitted: 28 March 2024 **Accepted:** 03 April 2024 **Published:** 09 April 2024

https://doi.org/10.63620/MKJAEES.2024.1033

Citation: *Muthuri, K., & Alibaba, H. Z. (2024). Natural ventilation strategies for high-rise buildings in the Mediterranean region. J of Agri Earth & Environmental Sciences, 3(2), 01-07.*

Abstract

Highrise buildings' efficiency in the Mediterranean region has various challenges related to energy consumption and climate for the comfort of the users. My article will be exploring the strategies and solutions of natural ventilation for sustainable energy use. Passive cooling strategies such as natural ventilation is important in this region as cooling loads can be high.

The climate in the Mediterranean is hot and dry in the hotter seasons while it is cool and wet in the colder seasons. Natural ventilation would be ideal for any structure in this region. Effective strategies are needed to improve indoor air quality and reduce dependence on mechanical systems like Heating, Ventilation, and Air Conditioning (HVAC) systems. This will result in the reduction of running costs and energy sustainability towards the net zero goal. To achieve these, it is best solved from the design stage and operational decisions for optimal natural ventilation through building orientation, shading devices, façade design, and use of smart control technologies.

Challenges such as fast wind speeds and turbulence in Highrise buildings in the region have required different strategies for effective natural ventilation. The building's orientation should maximize the inflow of the prevailing wind and minimize the penetration of direct sunlight. If direct sunlight is unavoidable shading devices are used as overhangs, louvres, and awnings to reduce heat gain. Windows are to be designed and placed in areas that maximize airflow. An effective method has been the crossflow ventilation that allows the flow of air through a building from one end to the other. Stack effect is used to allow airflow into a building through the creation of pressure difference between the outside and inside of the building. This is achieved through vents, chimneys, and other openings. Another method is the use of wind catchers that capture wind and channel it into the building.

To complement the design strategies are other operational solutions such as Occupants control the opening and closing of the openings to regulate the thermal comfort and airflow. Automated systems will automatically open and shut the openings based on the internal and external conditions for regulation of temperature levels. Another way is as temperatures cool when the sun sets, the night ventilation can be used to cool the interior of a building as outdoor temperatures are low.

Knowledge of the measures to be taken for the successful implementation of natural ventilation should also be passed on to the occupants of the buildings. By educating and promoting environmentally conscious behaviors it can contribute more to sustainable performances of Highrise buildings in the region.

The focus on the Mediterranean region, the research is to find solutions on the potentials of natural ventilation to improve building sustainability, reduction of energy consumption with focus of the net zero goal and always maintain usability comfort. By using the energy plus software for simulation it provides insight on the solutions of the built environment in the Mediterranean context.

Keywords: Highrise Buildings, Mediterranean Region, Natural Ventilation, Sustainability, Methods, Strategies.

Introduction

In the Mediterranean region, architecture is challenged by the climatic conditions, among others. Utilization is there and methods to mitigate the unnecessary is a major factor in design must be evaluated and ensure proper energy use, so I focused on using little to no mechanical ventilation through natural ventilation systems in buildings. As the world shifts to net-zero goal to combat climate change, natural ventilation systems are one of the many sustainable strategies and provide a comfortable environment for the occupants.

The climate in this region is known for the extremely hot summers and gentle winters which are ideal for the use of natural ventilation solutions. Innovation in architecture is to be incorporated in design for energy efficiency. This article aims to go into the use of natural ventilation in support by little to no mechanical ventilation use in high-rise structures in the region.

By exploring the unique climatic challenges in the Mediterranean region. The intensity of the summer's heat and variability of the winter season, by understanding the natural ventilation harnessing is a step towards a sustainable solution. Understanding through the perusal of different published works I approached the design principle and methodologies that could help maximize the potentials of natural ventilation through simulation on a high-rise structure I designed with exact conditions of a Mediterranean structure in the region.

Natural ventilation's possibilities can only be fully utilized through design decisions such as building orientation that would incorporate façade design and passive solar integration. Openings are strategically placed to capture airflow naturally and distribute it into the structure. The use of artificial computerized systems can also be utilized as it enables efficient work due to the advancements that have been brought by the advancements of technology. This will enable the great advancement in the evolution of sustainable construction and the lifecycle of high-rise structures.

The success of natural ventilation methods in high-rise buildings has a lot to be considered with the points of design and technological integration. The success also comes down to how the occupants use the system. By ensuring that the users are aware of the system allows the cooling in the summers and heating winters are lost due to lack of awareness or ignorance. Natural ventilation is to utilize what nature provides, such as sunlight and air. By making it part of the culture to be environmentally conscious and empower the high-rise occupants through knowledge.

The goal of this research is to analyze and see the potential of sustainable design decisions in this case natural ventilation as I have researched through case studies. As direct influences in the built environment designers, engineers, other consultants, and policymakers may see the comprehensive view of having natural ventilation systems integrated in high-rise buildings within the Mediterranean region. Sustainability strategies will help conserve our environment. Exploration within the field of conservation methods in a sustainable manner will breathe new life in architecture as we continue to advance as human beings and the environment we live in; the possibilities are vast.

Literature Review

In the thesis, "Natural Ventilation Buildings – Architectural concepts, consequences and possibilities." by Tommy Kleiven [1]. He focused on the natural ventilation use in buildings as an avenue to see the possibilities and consequences architecturally. Primarily natural ventilation affects the layout and organization of interior spaces, façade design, the silhouette, elevation, and roofing. Principles applied to the ventilation approach have different methods influenced by cross, single-sides and/or stack ventilation systems, which together with natural supply can extract paths. Using these systems, whether centralized or localized, is important in studying the consequences and possibilities of it in architectural eyes. Mechanically ventilated structures are the easiest buildings to design compared to naturally ventilated buildings. During the initial design stages the interdisciplinary approach is key as it is mandatory to construct a successful structure that uses natural ventilation to intermarry with the natural environment. Kleiven's investigations and studies were done in Northern Europe with the use of case studies and interviewing of architect and HVAC consultants to collect his data. On top of the collected data through interviews he had the opportunity to study three built structures namely GSW Headquarters in Germany, B&O Headquarters in Denmark, and the Media Primary School in Norway.

In the thesis, "Natural Ventilation Building Design Approach in Mediterranean Regions – A Case Study at the Valencian Coastal Regional Scale (Spain)." by Miguel Mora-Perez, Ignacio Guillen-Guillamon, Gonzalo Lopez–Patino and Petra Amparo Lopez-Jimenez [2].

Awareness of the Environment continues to spread in the world and has proven time after time that it leads to better through the increase in awareness and concern on how to incorporate low-carbon technologies into our lives. Natural ventilation is among the areas where technological integration is needed and requires implementation with thorough evaluation before starting construction. Software such as Computation Fluid Dynamics has made it easier to make design approach studies. Incorporation of CFD allows the input of wind conditions as well as the environment to show the building's surroundings for sustainable and suitable solutions architectural approaches for indoor comfort is important, this will help in evaluation and making of the final decision to the façade opening distributions. Natural ventilation design approach has proven to improve a building's energy performance by up to 9.7% especially if included in the initial stages of design.

In the thesis, "Natural ventilation potential of the Mediterranean coastal region of Catalonia." by Nikola Pesic, Jaime Roset Calzada, Adrian Muros Alcojor [3]. According to Koppen-Geiger's climate classification there are different climate types within the Mediterranean coastal region. The incorporation of building energy simulation software helps give the refrigeration energy saving data. Potential natural ventilation (NV) application designs and demonstrations of the region's effects due to the climatic variations can then be determined. In Tarragona, Barcelona, and Terrassa where the studies of the different climatic potentials studies were done to see if viable for the natural ventilation system due to the yearly correspondence such as mixed-mode(hybrid) and nigh-ventilation techniques that can be integrated to buildings in these cities.

In the thesis, "A new design to create natural ventilation in buildings: Wind chimney." by Jalil Shaeri, Mohammadjavad Mahdavinejad, Mohammad Hossein Pourghasemian [4]. Urban population increase and the global warming crisis require passive solutions from various industries that influence them indirectly and/ or directly, especially construction. Creative passive elements and novel elements for creation of natural ventilation channels into buildings in coastal areas and areas prone to prevailing wind flow should be utilized. Computation fluid dynamics (CFD) software integrated in the COMSOL Multiphysics software allows the use of wind tunnels for studying purposes. Novel elements in the play will work accordingly to aerodynamics law and air pressure difference due to wind flow called wind chimneys. CFD allows different scenarios with the scenarios simulated where the chimneys were either on one side of a building or in the center of the building with the conditions set like those of Bushehr, Iran. The chimney in the center was better as it would allow better aerodynamics for airflow into the structure compared to the chimneys on the side of the same building in similar conditions.

In the thesis, "A study of different envelope scenarios towards low carbon high-rise buildings in the Mediterranean climate - can DSF be part of the solution?" by Tanya Saraglou, Theodoros Theodosiou, Baruch Givoni, Isaac A. Meir [5]. High-rise buildings are rapidly on the rise. The rapid evolution required to have the design of high-rise buildings respond to local climate is not in play but very much necessary. High- energy loads have been rising due to increased use of glass and other materials that allow transparency into high-rise structures. Energy load reduction will be brought down significantly with the incorporation of passive design strategies. Using the Energy plus thermal software, it has shown results that the main passive design strategy to employ is adaptive building envelope. Double skin façade (DSF) and single skin envelope when used in hot and humid climates has been one of the best solutions so far in lowering cooling loads. LowE glazing as the interior layer with the support of external shading elements performed even better for the double-skin envelopes. LowE glazing on the exterior layer increased the energy efficiency for DSF in mediterranean climate after weighing the other three options. DSF indeed does have more benefits over the others even better when incorporated with the external shading element types.

Methodology

The methodology used to explore this case involves computer software, these are computer-aided design software and simulators. As they would help in developing the 3D model that would provide the characteristics of a building and its functions and in this case the openings for air flow in and out of the building for natural ventilation scenarios.

I generated a 3D model as I set the site conditions of a Mediterranean environment. The geometry of the building is like that of a typical office building and uses a grid of 8 meters by 8 meters for space allocation internally.

As the natural ventilation aspect would be simulated through Computational Fluid Dynamic (CFD) analysis in the BIM platform to bring results. By ensuring the openings and orientations were imitating those of the real world the examining of natural air flow would determine the cooling of the high-rise building.

Upon making the 3D model and uploading it into the CFD simulator to process the data, initiate the simulation and give results. Trials and changes were made to adjust the parameters to fit those of the ideal environment for the case in hand as slight changes bring varying results. At the end of the process, the results are generated for the purpose of analysis and allow the user to study whether the case in hand works for them structure.

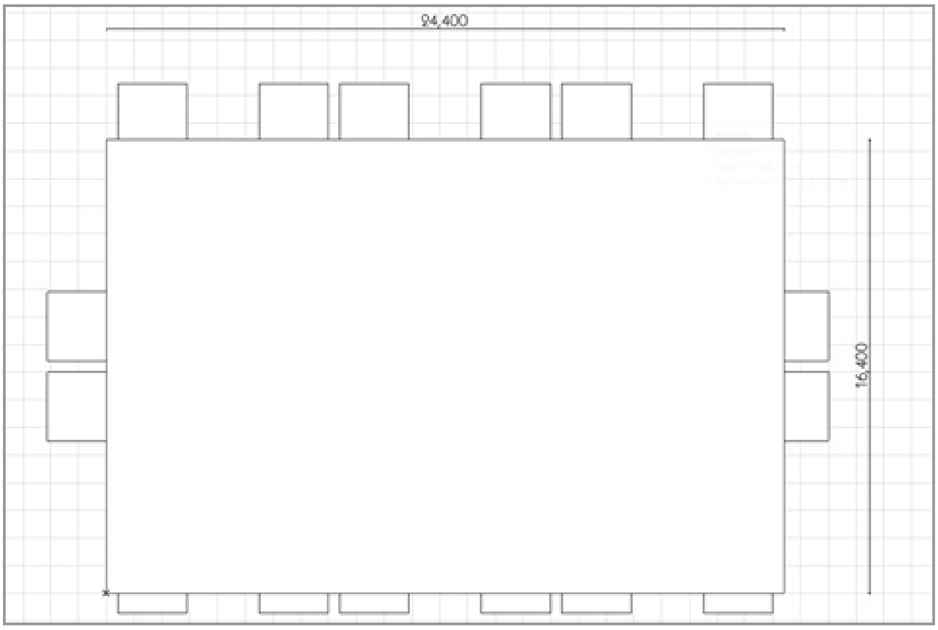

Figure 1: Model Top View Simplified Plan with Dimension in mm

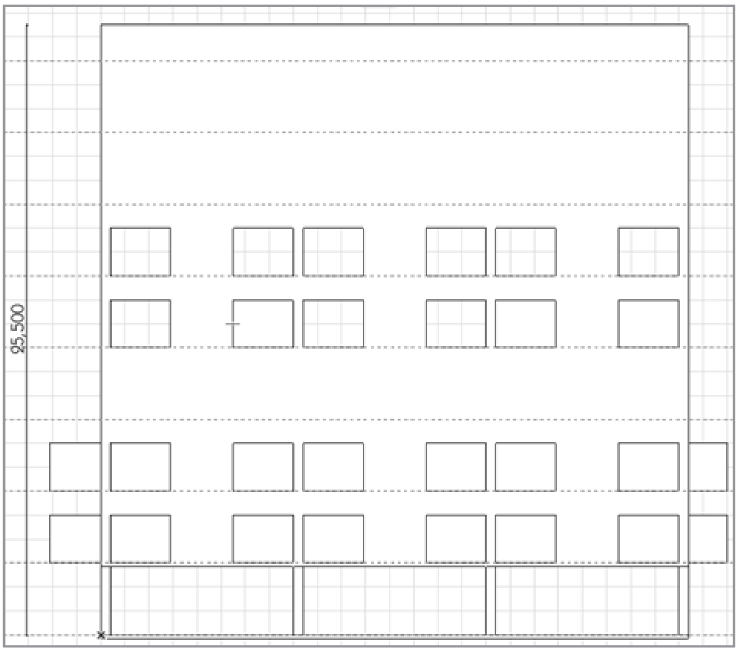

Figure 2: Model Elevation with Dimension in mm

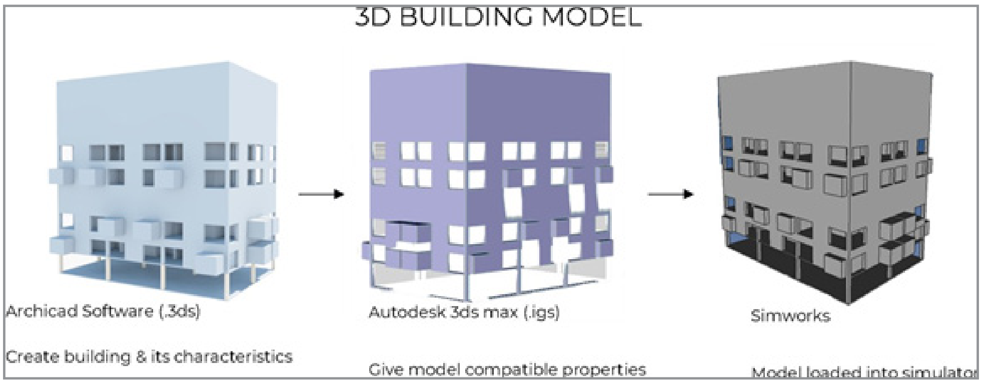

Figure 3: 3D building model process from BIM to CFD

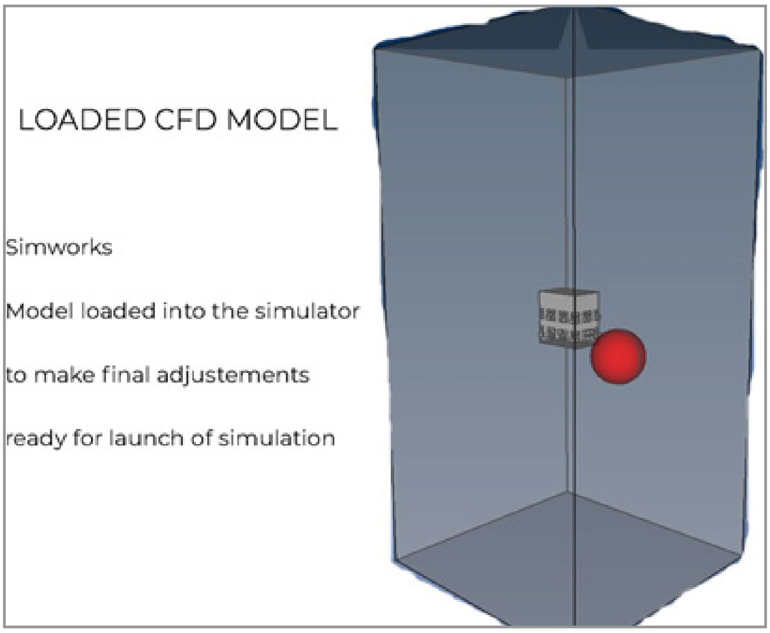

Figure 4: Loaded model into CFD for simulation to begin

The planning and model made on ArchiCAD is simplified on Autodesk 3ds max for compatible parts that are essential to work on the SimWork simulator as shown in Fig.1,2&3. The external conditions for air to pass through the building for natural ventilation are incorporated. Within the rectangular volume created is the environment that was going to project the calculations from the artificial surroundings demonstrated in Fig.4.

Defining the conditions in the wind flow would be 5m/s as this was also the limit provided by the simulator but also ideal for the day- to-day wind flow in natural environments. The simulator then proceeded to compute the change in temperature as the wind flowed into and out of the model. The computation results were provided with both numbers, charts, and 3D maps for proper analysis of the content with the given conditions.

Results and Discussions

The process of getting the simulation working for the methodology chosen, I transferred the model to various software to ensure compatibility to the simulator. By saving the model in different file types and editing some items would lose the data commutated thus changing some properties. SimWork would also change the properties of the model's surfaces and would have to be commutated once more for accuracy. Using CFD software is quite complex as it requires the input of incredibly detailed data that a new user to the CFD space would find difficult to use such as environmental conditions for ideal air flow and pressure release commutations amongst others. The whole procedure of transferring through different software, adjustments due to lost data and input of the detailed data were time-consuming as the simulation had not yet begun.

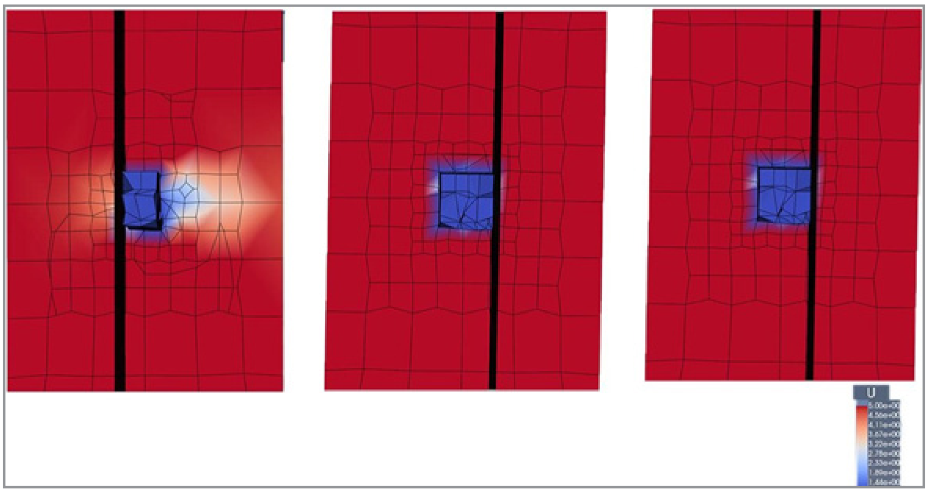

Figure 5: Temperature Change as Air Flow Cools the Interior

As Natural ventilation strategies are needed for sustainable architectural solutions in the Mediterranean, especially in high-rise buildings, this strategy stands high in the conservation of resources. As I have seen through the analysis of the SimWork simulation it has enlightened me on the effectiveness of natural ventilation and the different combination of strategies to optimize energy use while resulting in ideal comfort for the users/ occupants [6].

As the wind velocity was varying from 0.5m/s to 5m/s with variations of openings the air flowed through the building thus reducing the temperature as it pushed the warm air out the cooler air took its place as seen in fig.5. This meant that air flowed on the inside well enough to cool it.

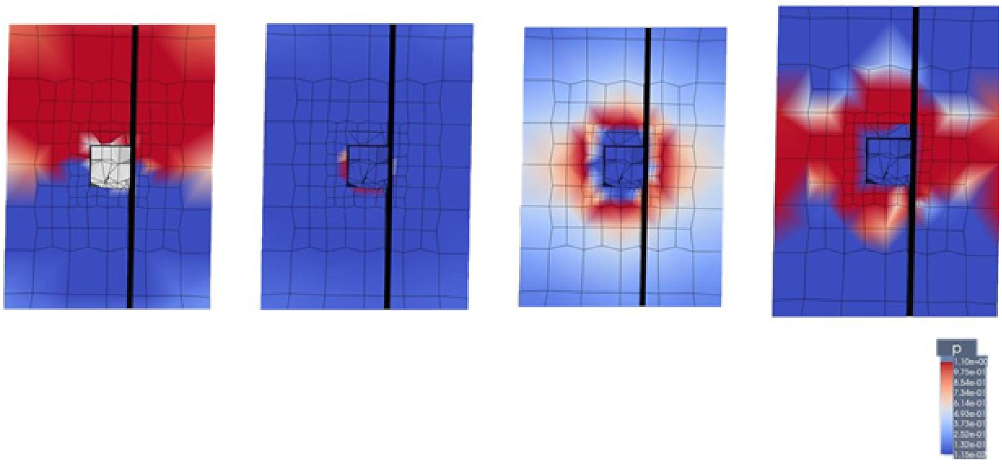

Figure 6: Temperature Change and Release of Pressure

Air temperature and utilization for cooling purposes will occur in the hotter seasons which means the use artificial heating is then used during the cooler season in the winter which is around three months compared to the warmer period of nine months. In hotter seasons the air is cooler if it has a higher velocity, so the orientation and sizes of openings need to be ideal for the purposes of capturing this natural opportunity. As seen in fig.6 the temperature and velocity of air influence the cooling process in the building. As the large openings in the building were in use to allow in flow and out flow, the pressure on the building is eased up as the flow cools the building and pushes out the air. This shows that natural ventilation during cooling is ideal.

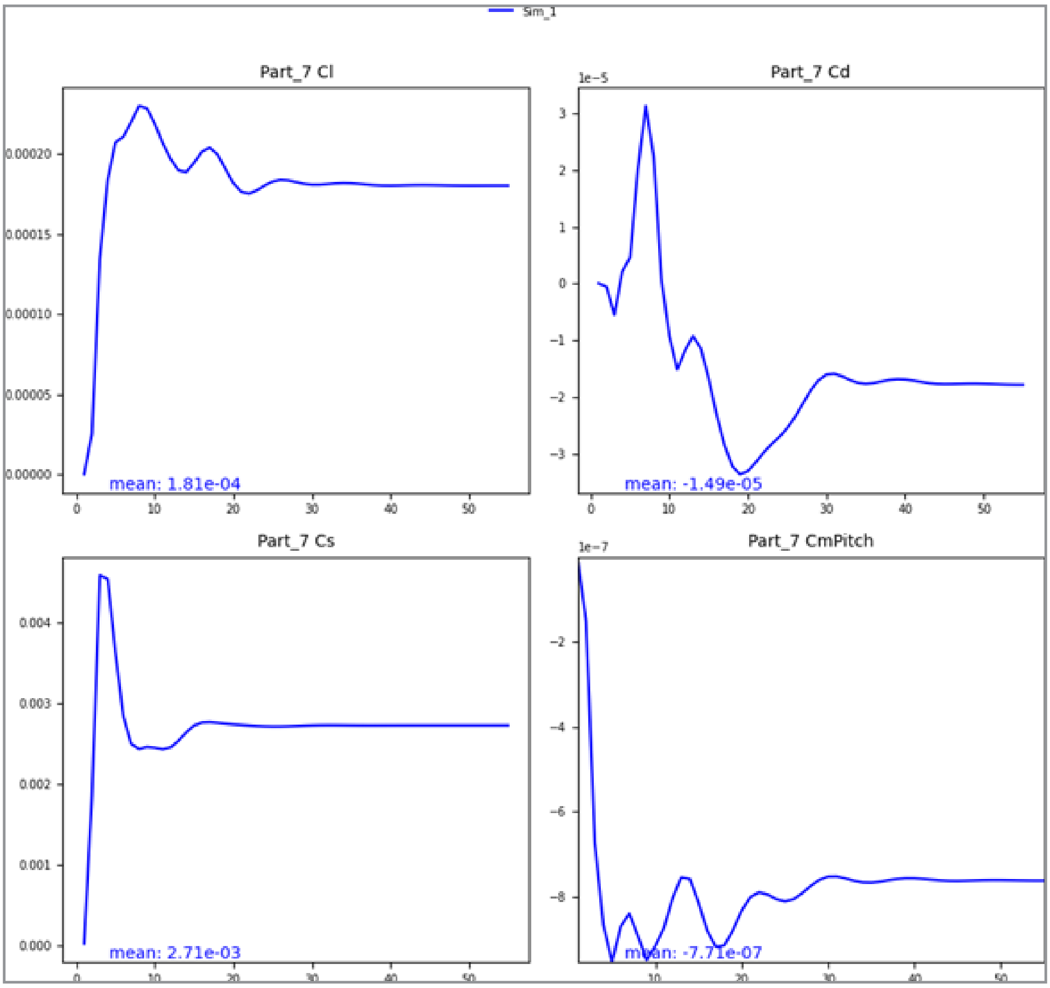

Figure 7: Temperature and Air Flow Stabilization with Release

As seen in fig.7 the temperature and velocity are controlled by the openings, orientation, façade design and use of the building as they stabilize after initially being let to flow through the structure. Taking advantage of the air velocity during warmer seasons helps in cooling as it is also ideal for the human skin, the indoor comfort that can be adjusted should ensure adaptable measures of cooling such as natural ventilation is incorporated. This will help in the reduction of electricity use by building users.

Conclusion

Overall, demand for high-rise buildings has grown over the years to accommodate the needs of human beings in the urban centers. Expertise on how to design high-rise buildings in response to local climatic need should always be considered. Passive design strategies have proven to be of immense importance in reducing energy loads. The main strategies being the building envelope, stack-effect, and ventilation strategies such as daytime, night-time, and full-day ventilation. My study has proven that airflow into buildings through the openings has a significant benefit to the cooling effect of the building which would result in lower energy consumption which in the end benefits the users as they conserve resources. The parameters set in the simulations with the Mediterranean region typical conditions, building geometry in play and openings as the points of entry for the wind flow. The simulation showed wind flow into the building brought cooling effects ideal for thermal comfort. The building orientation, façade design, passive solar design, passive solar principles, use of artificially intelligent controlled systems and knowledgeable occupants are also in play for a building to have sustainable ventilation systems running in buildings.

References

1. Kleiven, T. (2003). Natural ventilation in buildings: Architectural concepts, consequences and possibilities (Doctoral thesis). NTNU Open, Institutt for Byggekunst, Historie og Teknologi. https://ntnuopen.ntnu.no/ntnu-xmlui/

handle/11250/231090
2. Mora-Pérez, M., López-Pérez, G., & Llopis-Julián, P. (2016). Natural ventilation building design approach in Mediterranean regions—A case study at the Valencian coastal regional scale (Spain). Sustainability, 8(9), 855. https://doi.org/10.3390/su8090855
3. Pešić, N., Roset Calzada, J., & Muros Alcojor, A. (2018). Natural ventilation potential of the Mediterranean coastal region of Catalonia. Energy and Buildings, 169, 236–244. https://doi.org/10.1016/j.enbuild.2018.03.063
4. Shaeri, J., Mahdavinejad, M., & Pourghasemian, M. H. (2021). A new design to create natural ventilation in buildings: Wind chimney. Journal of Building Engineering, 59, 105041. https://doi.org/10.1016/j.jobe.2022.105041
5. Saroglou, T., Theodosiou, T., Givoni, B., & Meir, I. A. (2019). A study of different envelope scenarios towards low carbon high-rise buildings in the Mediterranean climate—Can DSF be part of the solution? Renewable and Sustainable Energy Reviews, 113, 109237. https://doi.org/10.1016/j.rser.2019.109237
6. Pešić, N. (2020). Geo-climatic potential for advanced natural ventilation comfort cooling approach in mid-rise office buildings in the north-western Mediterranean (Doctoral thesis). Universitat Politècnica de Catalunya. http://hdl.handle.net/2117/340967