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Computational fluid dynamics (CFD) tools in architectural design studios: case study

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SCOPE

The Growing concerns about indoor air quality (IAQ) and thermal comfort in the residential sector, particularly after the COVID-19 pandemic, underline the importance of ventilation optimization [1,2]. Airflow and pollutant transport are a complex mechanism. In this digital era, advanced tools - in particular computational fluid dynamics (CFD) - have become the primary method for solving these problems quickly and efficiently [3].
The building's indoor climate largely depends on the decisions made by the architect during the early design work. In architectural pedagogy, the architectural design process is a creative one, as students are sensitive contributors to the strong link between environment and architecture. Consequently, they face increasing pressure to design environmentally friendly buildings.
The study examines the integration of computational fluid dynamics (CFD) into the design process as a component of a student's overall project design. The aim is to identify some of the challenges faced by students integrating CFD simulation methodologies during a studio design process, and to advocate consideration of design problem-solving models and preferences for indoor air quality (IAQ) and ventilation improvement.

METHODOLOGY

The study was conducted on a design project within an architectural design studio. It aimed to assess the project's resilience to external climate factors through testing and simulation, validating the design and predicting building air quality from the early design stage. Computational Fluid Dynamics (CFD) Air Flow Analysis using Ecotect and the multi-zone model CONTAM were employed to model the building's layout, internal partitions, and complex airflow paths according to Fig.1.

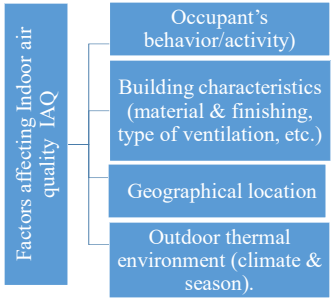

Fig 1.Factors affecting Indoor air quality IAQ

SIMULATION TOOLS

A classification method for simulation tools, proposed by Massimo Palme and M. Massetti developing their PhD thesis as shown:

Complexity	• levels of precision (finite elements)
Transparency	• Inputs clarity
Design impact	• Rapidly and easily to modify the simulation object
Uncertainty	Results change significantly when input parameters hange

SOFTWARE USED FOR IAQ SIMULATION

WinAir for Ecotect:
WinAir is a plugin to perform CFD analysis (wind flow) on a mesh using Ecotect.

CONTAM Software (Multi-zone model)
Multi-zone modeling with CONTAM software has the ability to model air mass and contaminant concentrations in buildings with internal partitions (multi-zone

RESULTS AND DISCUSSION

WEATHER INPUT:

The minimum requirements for ventilation modelling are side wind velocity (speed and direction) and external temperature. Climate Consultant 6 was referenced to find the appropriate wind direction and velocity for the site -60 degrees (northeast) in the summer and 200 degrees (south-west) in the winter, with an average wind speed of 1.41 meters per second. (Fig 2)

CONTAMINANT SOURCES

The pollutant present in the simulations is CO2, the generation rates is derived from human metabolism and exercise physiology, which relate these rates to body size and composition, diet, and level of physical activity.

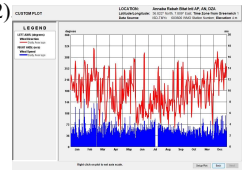

Fig 2.Wind speed and direction

PROJECT DEVELOPMENT

MODEL GEOMETRY

The model contains 03 blocks (17 levels). The project design incorporates the concepts of Pocket Park and the Breathing Architecture.

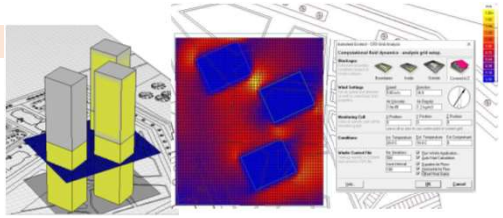

Fig 3. Project layout

- the blocks are oriented diagonally at 24° to the west to maximize ventilation and increase the number of facades exposed to winds .
- The buildings are set back from the road to minimize noise, and pollution
- Air-purifying trees, such as oaks planted around the buildings.
- Undeveloped areas utilized to create pocket parks.
- The esplanade planned for the second floor designed as a pocket park, continuing the exterior layout (Fig 3& 4).

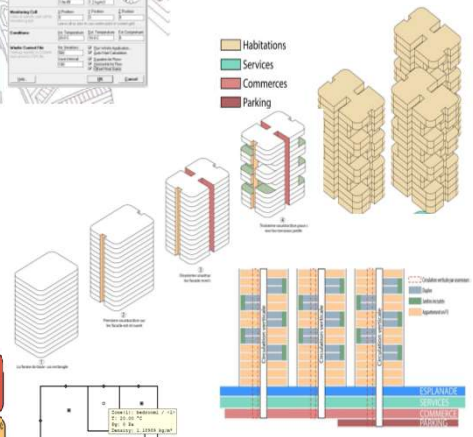

Fig 5 .Diagram of the genesis of the volume of housing blocks

F3 apartment design (three bed room):

- The entrance is designed as a disinfection station.The living room is flexible, opening onto the kitchen and offering the possibility of adding a decontamination area.All rooms benefit from natural ventilation (Fig 05).

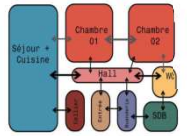

Fig 5. F3 apartment design

Description of the Spatial Organization of F3 and F4 Duplex Apartments

- Master bedrooms are equipped with private bathrooms to address contamination concerns. Rooms are spread over two floors, each with its own bathroom to ensure optimum containment in the event of a health crisis. (Fig 6)

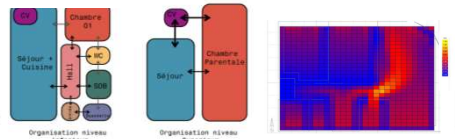

Fig 6. F4 duplex apartment design

CONCLUSIONS

The analysis of contaminant distribution and concentration is crucial for assessing indoor air quality (IAQ) as it directly influences the health and well-being of occupants. The building's ventilation system plays a key role in the intricate process of pollutant distribution in the air. Without a proper understanding of CFD fundamentals (, results can sometimes be "dangerously inaccurate."

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