ENAC / PROJET DE MASTER 2021-22
SECTION DE GÉNIE CIVIL

Investigating the impact of different natural ventilation modes on indoor air quality and overheating

Auteur(e)s : Louis Dupart

Encadrement : Prof. Licina Dusan [1] / Evangelos Belias[1]

[1] The Human-Oriented Built Environment Lab (HOBEL) EPFL

Introduction

- On average, 70 years out of 79 years life spent indoor[1]. To achieve good indoor air quality [2]:
  - Minimize indoor emissions
  - Keep the air dry
  - Protect agaisnt outdoor pollution
  - Ventilate well

  Study focus
- Natural ventilation is the flow of air through purpose-built building envelope openings by natural forces, depending on climate, human behavior and building design.
- Major European pollutants: PM2.5, PM10, O3, NO2 & SO2. They cause cardiovascular and respiratory diseases & increase mortality
- Literature gap & objectives: limited investigation (PM2.5) on non-residential building [3], no studies on outdoor air pollution penetration and overheating in residential buildings and different natural ventilation modes influence them.

Conclusion

- Demand control ventilation reduces the outdoor pollution penetration compared to standard mechanical ventilation (without filter)
- Natural ventilation (model 2 & 3) solves the overheating issue.
- But when outdoor air pollution is considered (model 4), it reduces pollutant mean and peak penetration at the cost of a significant increase in overheating
- Through infiltration, walls act as a filter for pollutant in older building

Follow-up

- Optimization of the algorithm of the model 4 window control
- Creation and experimentation of a controllable window with air sensor

Methodology

Data collection

- 11 cities: 95 stations
- TAPY: Typical Air Pollution Year obtain from station data.
- TMY: Typical Meteorological Year obtain from [4], named EPW
- Building information obtain from the Tabula Webtool

FIGURE 2: CITIES STUDIED

Modelisation

- Shoe box model: 3,6m/5,5m/2,8m
- Window facing west
- Parameters by country:
  - Window dimensions & structure
  - Walls constitution
  - Infiltration rate

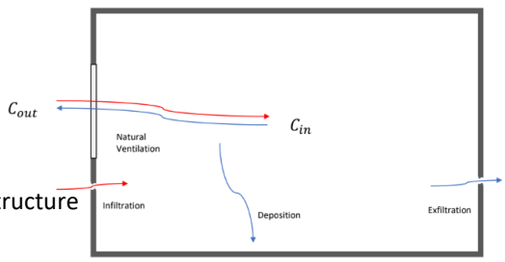

FIGURE 2: POLLUTANT FLUX AND INTERACTION WITH THE SHOEBOX

Mass balance model

$$\frac{dC_{in}(t)}{dt} = P \cdot \lambda(t) \cdot C_{out}(t) + \frac{Q_V(t)}{V} \cdot C_{out}(t) - \lambda(t) \cdot C_{in}(t) - \frac{Q_V(t)}{V} \cdot C_{in}(t) - k \cdot C_{in}(t)$$

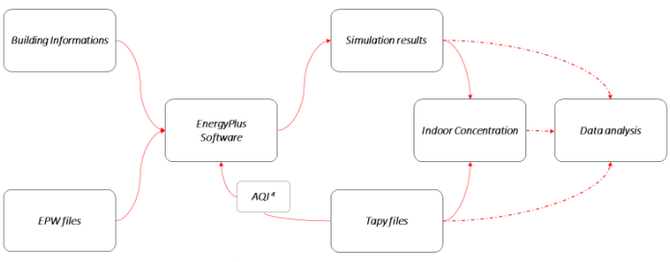

FIGURE 3: WORKFLOW OF THE SIMULATIONS

Simulation

- From the building model for each country, the EPW files of a city and the Tapy files of a station, the 4 ventilation modes are simulated in EnergyPlus.
- From the simulations results, the ventilation rate Qv and infiltration λ are computed.
- Using the dynamic solution of the mass balance model equation, the hourly indoor concentration for the 5 pollutants are computed in Matlab

Ventilation modes

- Model 1: Continuous mechanical ventilation (European Standards)
- Model 2: Scheduled natural ventilation (3 times a day for 10 mins and ventilative cooling during summer)
- Model 3: Demand-based natural ventilation (based on indoor/outdoor temperature and humidity and indoor CO2 concentration)
- Model 4: Demand-based natural ventilation as the model 3, but with an additional parameter: AQI (Air Quality index parameter obtain from the Tapy Files). The AQI parameters force the window to close when outdoor concentration (station data) reach a threshold based on WHO guidelines.

References

[1] Klepeis, N.E., Nelson, W.C., Ott, W.R., Robinson, J.P., Tsang, A.M., Switzer, P., Behar, J.V., Hern, S.C., Engelmann, W.H., 2001. The National Human Activity Pattern Survey (NHAPS): a resource for assessing exposure to environmental pollutants. J Expo Sci Environ Epidemiol 11, 231–252. https://doi.org/10.1038/sj.jea.7500165
[2] Nazaroff, W.W. (2013), Four principles for achieving good indoor air quality. Indoor Air, 23: 353-356.
[3] Martins, N.R., Carrilho da Graça, G., 2017. Simulation of the effect of fine particle pollution on the potential for natural ventilation of non-domestic buildings in European cities. Building and Environment 115, 236–250. https://doi.org/10.1016/j.buildenv.2017.01.030
[4] https://power.larc.nasa.gov/data-access-viewer/