Doctoral Seminar 2018

Natural Ventilation Effectiveness in Single and Multi-Storey Buildings

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Proposed Research

Background:

- The good Indoor Air Quality (IAQ) is a basic human right and it is essential for health and productivity (Persily, 2015; Sundell 2004, Horr et al., 2016).
- The relation between IAQ and ventilation flow rate is complicated due to confounding factors (Burge et al., 1987)
- One of the confounding factors is the local air flow distribution in an occupied domain (Redlich et al., 1997).
- With low ventilation effectiveness (non-homegenous fresh air distribution), both IAQ and energy efficiency suffers (Sandberg, 1981; Seppänen, 2008).
- Natural ventilation is an effective strategy to provide healthy and energy efficient buildings (Short et al., 2004)

Research Gap:

- Mechanical ventilation effectiveness had been investigated throughly (Cao et al., 2014).
  
  But

- Research lacks ventilation effectiveness studies in natural ventilation context in single and multi-storey buildings.
Aim: To propose a new year-round natural ventilation efficiency values capable of providing improved guidance over existing design guidelines for the design and operation of energy efficient naturally ventilated single and multi-storey residential buildings.

Objectives:

OB1: Review the literature to identify the strengths and shortcomings of existing performance metrics, modelling and experimental methods.

OB2: Define a typical single storey residential building geometry, appropriate boundary conditions, and NV system scenarios that encapsulate all the building physics that needs to be tested.

OB3: Conduct experiments to measure MV and NV local air change index and heat removal efficiency, and indoor environment parameters to validate the single storey CFD modelling predictions and to provide boundary conditions for CFD modelling.

OB4: Create a dynamic thermal simulation (DTS) model of the single storey building to obtain surface temperatures at specific boundary conditions which can then be compared to laboratory findings and transferred (if required) to the computational fluid dynamics (CFD) models.

OB5: Create the CFD models of the ventilation scenarios performed in the laboratory for single side and cross flow NV, mixing and displacement MV to predict local air change index and heat removal efficiency, and indoor environment parameters.

OB6: Compare the experimental results (from objective 3) and the modelling results (from objective 5) to create a single storey ventilation baseline performance and assess the statistical correlation between different ventilation performance metrics.

OB7: Use DTS and CFD to simulate single sided and cross flow NV scenarios with various opening configurations for a single-storey building in summer and winter conditions and compare performance findings with baseline performances to propose design interventions.

OB8: Create a multi-storey building for DTS and CFD modelling by using a similar floor plan of the single-storey building. Assess the ventilation effectiveness to create the performance baselines by relevant IAQ and heat removal metrics for single sided, cross flow, atrium, wind tower and solar chimney applications individually and in a combined configuration.

OB9: Introduce appropriate case study building and perform field measurements to validate multi-storey CFD models.

OB10: Implement NV design changes to multi-storey theoretical building models to assess the improvement in the ventilation effectiveness and establish appropriate design thresholds for the use of a year-around ventilation efficiency metrics.

OB11: Develop industry design guidance to contribute to the existing NV guidelines by proposing year-round ventilation efficiency values and suggesting effective NV solutions for single-storey and multi-storey buildings in accordance with the findings.
Objectives Flow Chart

**Geometry & Boundary Conditions**

- **Single-Storey CFD and DTS Modelling**
  - Validation of single-storey CFD model

**Experiment**

- Tracer gas decay method and measurement of environmental parameters

**Multi-Storey Case Study Building**

- Measurements in cooling season
- Incorporates common natural ventilation applications

**Post Validation Modelling**

- Comparison to multi-storey CFD model predictions

**Results**

- Contributions to Academia and Industry

**Temperature Measurements**
Preliminary Modelling
Preliminary Modelling
Preliminary Modelling

Temperature
ZY plane

- 2.950e+02
- 2.943e+02
- 2.935e+02
- 2.928e+02
- 2.920e+02

[K]

0 0.500 1.000 (m)
Preliminary Results

- Mass Flow Rate Upper Window (l/s)
- Heat Removal Efficiency
- Average Age of Air in the Whole Domain [s]
- Heat Loss From the Domain [W]
- Local Air Change Index [%]
- Global Air Change Efficiency [%]
- Average Age Of Air in Breathing Zone [s]
Preliminary Results

7 Degree Celsius Supply Temperature


Thanks!