Modelling Approaches to Natural and Mixed-Mode Ventilation

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UCL
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What's special about natural ventilation?

- What sets it aside from mechanical ventilation?
  - Smaller driving forces
  - Driving forces are less clearly understood and are not constant
  - ... and thus more challenging to predict
  - NV often inextricably linked to architectural form and fabric
  - ... thus attention to both architectural and services issues

- Why model?
  - Commercial
    - Client request
    - Compliance
    - Communication
    - Competition bids
  - Scientific
    - Uncertainty re. driving forces
    - New, innovative strategies
    - Dynamic behaviour
    - Non-linear behaviour

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Coverage of Presentation

- Concept design methods
- Analytical methods
- Dynamic thermal simulation
- Computational Fluid Dynamics
- Application example

Concept design

Psychrometric chart with comfort envelope

London

Hong Kong

Psychrometric chart with operating modes
Civil and Building Engineering

Concept design: simplified equations

- See paper by Lomas (2007), Energy and Buildings
- Architectural design of an advanced naturally ventilated building form
- Relatively straightforward equations can be used:
  \[ q(m^2/s) = \frac{QA}{\rho C_p \Delta T} \]
  \[ q \text{ free opening area, } A \text{ (m}^2\text{) } = \frac{Q}{V_A} \]
- ... to give useful concept design advice:
  \[ A_{\text{lightwell s-sector}} \rightarrow \frac{A_{\text{total floor s-sector}}}{v/C_{\rho \Delta T}} \]

Analytical methods

- Stack-calc

Dynamic Thermal and Computational Fluid Dynamics

What vs how:
- DTS and CFD both predict thermal and ventilation performance
- DTS – whole building for a whole year ~ coarse spatial resolution
- CFD – key spaces for a point in time ~ fine spatial resolution

Dynamic thermal simulation model

Dynamic thermal simulation results

Thermal performance predictions (graphical)
Dynamic thermal simulation results

Thermal performance predictions (tabulated)

<table>
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<th></th>
<th>Jan</th>
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<th>May</th>
<th>Jun</th>
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Exceedence temperature during working hours using TRY (excluding last 2 weeks July, August and first week of September)

Room    | Number of Hours | Average Int / Ext Temp Diff (°C) | Maximum Internal Temperature (°C) |
--------|-----------------|----------------------------------|-----------------------------------|
GF1     | 0               |                                  | 5.6                               |
FF1     | 11              | 9.7                              | 30.0                              |
FF2     | 3               | 7.1                              | 28.6                              |
FF3     | 22              | 8.1                              | 32.6                              |
FF4     | 606             | 18.4                             | 41.5                              |

`Coupled` DTS and CFD modelling

- Dynamic/historic behaviour can be represented in CFD simulation using DTS output
- Surface temperatures resulting from radiation
- Δ (heat flux in – heat flux out) = stored energy
- Prediction of solar gain

Computational Fluid Dynamics: ventilation performance

Computational Fluid Dynamics: fresh air distribution

Computational Fluid Dynamics: temperature distribution
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Computational Fluid Dynamics: the how ? question

Predicting the neutral pressure planes

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Integrated thermal comfort and CFD modelling

D. Fiala, PhD thesis, De Montfort University, 1998

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Concept design

Psychrometric chart with comfort envelope

Mixed-mode case study

Harm A. Webber Library and faculty building at Judson College, Elgin, USA
Judson college: hours of operation

<table>
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<tr>
<th>Level</th>
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Source: Short and Lomas, Building Research and Information, 2007

Comparison of predicted annual energy cost

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<th>Cooling</th>
<th>Fan</th>
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Source: Short and Lomas, Building Research and Information, 2007

Predicted horizontal temperature distribution (passive mode)

Level two and level four temperatures at 0.91m (3ft) above floor level

Predicted vertical temperature distribution (passive mode)

The future

- More coupling of CFD and DTS programs
- Simulation of control to optimise mixed-mode performance
- Time dependent modelling using CFD
  - Solution multiplicity
  - Development and stability of ventilation flows

Large Eddy Simulation...