The Natural Ventilation of UK School Classrooms
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Ventilation Modelling and Regulatory Compliance
Presentation Content

- How can modelling help us to design robust natural ventilation strategies
  - *Case studies that have informed school design*

- Ventilation modelling using CFD and DTS
  - *Examples of their use in school design*

- Is modelling alone sufficient?
Natural ventilation in large, non domestic buildings

Frederick Lanchester Library, Coventry

Design challenges for NV
• Deep plan
• City centre location
• 45W/m²
In 2004:  
25°C was exceeded < 1% of the hours of use  
28°C was never exceeded
Measured energy consumption

2004

- Queens Building
- William Morris (Coventry University)
- Air-conditioned standard typical (ECON 19)
- Air-conditioned standard GP (ECON 19)
- Library (Coventry University)
- Naturally ventilated open-plan typical (ECON 19)
- Naturally ventilated open-plan GP (ECON 19)

annual energy use [kWh/m²/hour]

Heating
Cooling
Electricity
How was modelling used?
- CFD modelling

ΔT ~ 4K
How was modelling used? - CFD modelling
How was modelling used? – *DTS modelling*

- $T \geq 28^\circ C \sim 11$ hours
School dining and assembly space – CFD model

- 200 occupants
- 50W/m²
CFD results: air flow patterns
CFD results: temperature distribution

Temperature gradient

Temperature (°C)

Height (m)
## Performance Standards

- **BB101**

<table>
<thead>
<tr>
<th>Thermal performance (2 of 3 to be met)</th>
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</thead>
<tbody>
<tr>
<td>- no more than 120 hours above 28°C</td>
</tr>
<tr>
<td>- average internal/external temp difference not exceed 5°C</td>
</tr>
<tr>
<td>- Internal air temp (when occupied) not exceed 32°C</td>
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<table>
<thead>
<tr>
<th>Ventilation performance (indoor air quality)</th>
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<tbody>
<tr>
<td>- average CO₂ concentration should not exceed 1500ppm</td>
</tr>
<tr>
<td>- max CO₂ concentration should not exceed 5000ppm</td>
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<tr>
<td>- capability for occupants to lower CO₂ conc to 1000ppm</td>
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<thead>
<tr>
<th>Ventilation performance (volume flow rates)</th>
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<tr>
<td>- minimum of 3 l/s/p</td>
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<tr>
<td>- average should not be less than 5 l/s/p</td>
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<td>- capability to achieve 8 l/s/p</td>
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Simulation results: *DTS and CFD*

<table>
<thead>
<tr>
<th>Room</th>
<th>Number of Hours Over 28°C Target is ≤ 120</th>
<th>Average Int / Ext Temp Diff (°C) Target is ≤ 5°C</th>
<th>Maximum Internal Temperature (°C) Target is ≤ 32°C</th>
<th>Maximum CO₂ concentration (ppm) Target &lt;= 5000ppm</th>
<th>Maximum average CO₂ concentration (ppm) Target &lt;= 1500ppm</th>
<th>Fresh Air Supply (l/s/p) Target = 8 l/s/p</th>
</tr>
</thead>
<tbody>
<tr>
<td>GF18</td>
<td>0</td>
<td>5.6</td>
<td>27.8</td>
<td>2229</td>
<td>1530</td>
<td>9</td>
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<tr>
<td>FF42</td>
<td>2</td>
<td>3.7</td>
<td>28.7</td>
<td>1508</td>
<td>994</td>
<td>9</td>
</tr>
<tr>
<td>FF31</td>
<td>1</td>
<td>3.3</td>
<td>28.6</td>
<td>1392</td>
<td>986</td>
<td>9</td>
</tr>
<tr>
<td>FF14</td>
<td>27</td>
<td>8.1</td>
<td>32.6</td>
<td>1391</td>
<td>1040</td>
<td>7</td>
</tr>
<tr>
<td>FF11</td>
<td>606</td>
<td>18.4</td>
<td>41.5</td>
<td>1901</td>
<td>1702</td>
<td></td>
</tr>
</tbody>
</table>
DTS results: *thermal performance predictions*

- High heat gains
- Single-sided
- Openings at one height

**Room** | **Number of Hours Over 28°C** | **Target is \( \leq 120 \)** | **Average Int/Ext Temp Diff (°C)** | **Target is \( \leq 5 \)** | **Maximum Internal Temperature (°C)** | **Target is \( \leq 32 \)** | **Maximum CO₂ concentration (ppm)** | **Target \( \leq 5000 \)** | **Maximum average CO₂ concentration (ppm)** | **Target \( \leq 1500 \)** | **Fresh Air Supply (l/s/p)** | **Target = 8 l/s/p**
---|---|---|---|---|---|---|---|---|---|---|---|---
GF18 | 0 | | | | | | | | | | | | 
FF42 | 2 | | | | | | | | | | | | 
FF31 | 1 | | | | | | | | | | | | 
**FF14** | 27 | 8.1 | 32.6 | 1391 | 1040 | 7 | | | | | | 
**FF11** | 606 | 18.4 | 41.5 | 1901 | 1702 | | | | | | |
Two-storey Primary School: CFD results

- 31 occupants
- 30W/m²
Two-storey Primary School: CFD results

- acoustic attenuation
- weak airflow

Speed (m/s)
Two-storey primary School: CFD results

predicting the neutral pressure planes
Two-storey Primary School: CFD results
Sixth Form School – CFD model

- 26 occupants
- 47 W/m²
Sixth Form School - CFD and DTS results

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<tbody>
<tr>
<td>&gt; threshold</td>
<td>&gt; 28C</td>
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<tr>
<td>Internal air temperature</td>
<td>45 hrs</td>
</tr>
<tr>
<td>Internal operative temperature</td>
<td>36 hrs</td>
</tr>
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Summary

- Modelling is useful:
  - DTS – compliance – *what* is happening (how much ventilation)
  - CFD – detailed analysis – *how* the ventilation is happening

- Modelling shows us that
  - Natural ventilation of schools in the UK is very feasible
  - But NV will not tolerate elementary errors (orientation, mass, shading, etc.)

- Is modelling alone sufficient?
  - ... of course not ... we need *the three Cs*