Natural Ventilation Solutions for Urban Designs to incorporate Acoustic Considerations

CIBSE NATURAL VENTILATION GROUP

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Natural History Museum
Cromwell Road,
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Ventilation Rates in Primary Schools

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Approach

- Schools:  
  9 Primary Schools (Reading area < 30 miles)  
  (3 weeks / school)

- Targeted age group:  
  10-11 years old children

- Measurements (9 schools):  
  objective & subjective evaluations  
  (repeated design) in 2 classrooms / school

- Performance tests (8 schools):  
  - Computer  
  - Pen & Paper
Physical measurements

- Air temperature & RH
- Globe temperature
- Air velocity
- Carbon dioxide (CO₂)
- Lighting
- Noise level (during tests)
- Airborne particles (PM₂.₅)
- Air change rate (SF₆ decay)
Performance tests

- PC – 9 tests (20 min)
  - Attention / vigilance
  - Perceptual speed,
  - Mental arithmetic
  - Working memory
  - Words recognition
CO$_2$ weekly pattern - during school hours (8 school building)

Time dependent average across 16 classrooms

![Graph showing CO$_2$ concentration over time with different supply sources and days of the week.](image-url)
% of time spent when CO₂ > 1500 ppm

![Graph showing % of time when CO₂ exceeds 1500 ppm vs. Mean CO₂ concentration during school hours. The graph includes data points for different air supply systems: Uncontrolled, Re-Circulated Air Supply, and Outdoor Air Supply. The curve fit is a Gompertz function with R² = 0.971.]
% of time spent at hot/cold conditions

% of time when Tglobe exceeds the range 20-24 C

Mean globe temperature during school hours (°C)

- Uncontrolled
- Re-Circulated Air Supply
- Outdoor Air Supply

Curve fit - Gauss R²=0.896
CO$_2$ weekly pattern – unvented classroom

Effect of closed windows (uncontrolled condition)
Daily CO$_2$ patterns in classrooms

Carbon dioxide (ppm)

- Uncontrolled
- Re-circulated Air
- Outdoor Air Supply
- Outdoor level
- Tests Start-End

School Guideline

Test period

Time (h)

07:00 08:00 09:00 10:00 11:00 12:00 13:00 14:00 15:00 16:00 17:00
**CO₂ during testing**

![Graph showing CO₂ levels during testing with Fresh Air Supply and Re-circulated Air.](image)

- **School Guideline**: Ventilation rates: 1 - 8 L/s per person
Effect of ventilation

Relative performance

6 schools, 215 pupils
Effect of temperature

1 School, 30 pupils

**CO₂ (ppm)**

- Tg=23.1±0.8°C
- Tg=25.3±0.4°C

**Relative Performance**

- Simple RT: p<0.03
- Choice RT: p<0.04
- Col. Word Vig: p<0.001
Conclusions

- The provision of fresh air supply reduced the concentration of classrooms pollutants (?) below recommended levels.

- Temperatures were easier to control at high ventilation rates.

- Without intervention and adequate window opening routines the existing ventilation rates in naturally ventilated school buildings remain below the minimum recommended levels.

- Increased ventilation significantly improved pupils’ performance by ~3% in attention and vigilance tasks and by 8-14% in tasks that require more complex skills such as spatial working memory and long term memory.

- Uncomfortable high temperatures significantly slowed down pupils’ reaction time even though good ventilation was provided.
Recommendations to the school pers.

- Equip classrooms with a monitoring device for: CO₂, temperature & relative humidity
- Take immediate actions for additional ventilation if CO₂ concentration exceeds 1000 ppm.
- Keep temperatures within comfortable range:
  - 20-22 °C Winter
  - 22-24 °C Summer
- Avoid moisture build up in classrooms and keep humidity levels below 60% during winter time.
- Create daily windows opening routines for the school:
  - Morning, before children arrive
  - During breaks
  - After school hours during cleaning, vacuum cleaning
- Use odourless cleaning agents.
- Remember that dirty carpets can pollute the indoor environment.
Recommendation to school building designers, facilities managers and other stakeholders:

- Ventilation should be provided to limit the concentration of carbon dioxide in all teaching and learning spaces to an average of 1000 parts per million (ppm) between the start and finish of teaching on any day. This is lower than the 1500 ppm recommended by Building Bulletin 101.

- Provide a minimum fresh air supply rate in all teaching and learning spaces of at least 8 L/s per person. It is worth noting that this fresh air supply rate falls within the recommendations of ASHRAE and other international standards.

- It is acknowledged that dedicated ventilation systems may be necessary to achieve the above targets.

- Provide means of controlling classroom temperatures to the limits specified earlier.
To avoid excessive overheating, it may be necessary to limit solar gain by utilising passive means such as thermal mass, orientation, fenestration and external/internal shading devices.

Based on observations during this study and related research it is recommended that wall-to-wall carpets are avoided.

The choice of opening windows and their location is important in the design of effective natural ventilation.