RELATIONSHIP BETWEEN VENTILATION, AIR QUALITY AND ACOUSTICS IN 'GREEN' AND 'BROWN' BUILDINGS

Alireza Khaleghi[1], Karen Bartlett[2], Murray Hodgson[2]
[1]Dept. of Mechanical Engineering, University of British Columbia, 2054-6250 Applied Science Lane, Vancouver, V6T 1Z4
[2]School of Environmental Health, University of British Columbia, 3rd Floor, 2206 East Mall, Vancouver, V6T 1Z3

INTRODUCTION

There is a close relationship between the three factors, ventilation (in general, the heating, ventilation and air conditioning (HVAC) concept/system), indoor air quality (IAQ) and acoustics, and the design of each influences the performance of the others significantly. The application of various standards, methods and criteria in building design results in different conditions and qualities of the resulting ventilation, air quality and acoustical environment in different buildings. This provides an opportunity for investigation and evaluation of the impacts of various design concepts on the internal environmental conditions of buildings.

The present study investigated the relationship between the building design concept and resulting environmental factors, and the relationship between these, in 'green' and conventional, non-'green' ('brown') buildings.

The reduction of energy consumption, using natural ventilation (if applicable) and by the design of the concept of 'green' buildings, is considered very seriously in building design nowadays. Of course, introducing a new type of HVAC system influences the ventilation, indoor-air and acoustical qualities directly. In order to evaluate the environmental factors comprehensively, spaces in both 'green' and 'brown' buildings were chosen such that different types of ventilation concepts/systems – forced-air, displacement and natural – were involved. This paper presents observations about the results and the relationships between them.

METHODOLOGY

The factors investigated in this study were acoustics, ventilation and IAQ. Following are details of the environmental factors measured:

- Acoustics [1,2]:
  background-noise levels (unweighted and A-weighted octave-band and total, NC, RC ll); mid-frequency reverberation times (RT_{mid}); noise isolation (octave-band, NIC).
- Ventilation [3]:
  air-exchange rate (ACH = air changes per hour); ventilation rate was quantified by measuring the air flow entering the spaces, and using the SF_6 tracer-decay method.
- IAQ [4,5,6]:
  (glass)fibre dust (fibre concentration); ultrafine particulates (ratio of indoor-to-outdoor PC, inside PC – 20% of outdoor PC; PC = particulate concentration, UPC = ultra-fine particulate concentration); Volatile Organic Compounds (VOC concentration);

In order to investigate the above components more comprehensively, spaces were chosen which were easy to access, and which included a broad range of HVAC systems, furnishings and acoustical treatments. Hence, three buildings on the UBC campus, with rooms which contained the types of spaces required for this study, and which were adjacent (and, thus has similar outdoor environmental conditions), were selected for monitoring. These three buildings were: 1) BUILD_K, a 'green' building with LEED Silver ranking, 2) BUILD_C ('brown') and 3) BUILD_M ('brown'). The buildings were located next to campus roads, but were generally in quiet external environments.

In view of the fact that the acoustical conditions in any space are a function of its geometry, furnishings and furniture density, the rooms investigated were divided into four main groups:

- Office spaces – these were generally small rooms with a maximum of two occupants. The spaces had natural or forced-air ventilation, with carpets and acoustic tiles, and generally high or low furnishing density;
- Small classrooms – these spaces were generally larger than the spaces in the first group; they had forced-air or natural ventilation systems, and the major distinction that they possessed acoustic ceilings;
- Large spaces with substantial acoustic treatment – this category included large-volume spaces ventilated with displacement and natural ventilation systems; they had acoustic tiles and were carpeted, and contained a high furniture density;
- Large spaces with some acoustical treatment – these spaces covered a wide range of common, large educational spaces with different types of acoustical treatment and furnishings.

This pilot study involved 13 rooms; because of the statistical limitations associated with such a small sample size, the results are more indicative than definitive.

RESULTS

The two main building concepts investigated were construction style (i.e. 'brown', hybrid or 'green') and ventilation-system type (i.e. natural, displacement or forced-air). Environmental factors were correlated with ventilation-system type and construction style. The results with the highest correlation coefficients between the ventilation-system concept and environmental factors can be summarized as follows:

• In spaces with natural-ventilation systems:
the levels of unweighted low-frequency and total noise were lower; the number of air changes per hour was lower; the fibre concentration was lower (due to the type of furnishings in the spaces surveyed); the ratio of indoor-to-outdoor UPC was high (due to no filtration and inadequate control of outdoor air); the indoor temperature was lower at the time of monitoring (i.e. winter).
• In spaces with displacement ventilation systems:
the unweighted and A-weighted mid-frequency noise levels were high; total A-weighted sound-pressure levels were higher; the NC level of the noise was higher (because of nearby exhaust fans).
• In spaces with forced-air ventilation systems:
the unweighted low-frequency and total sound-pressure levels were high; the number of ACH was higher; the fiber concentration was higher (due to the type of furnishings); the ratio of indoor-to-outdoor PC was significantly lower; the indoor temperature was higher at the time of monitoring (i.e. winter).

The results with the highest correlations between the environmental factors and construction style can be summarized as follows:
• in 'brown' buildings:
the NC level was lower than in hybrid and 'green' buildings; this was mainly due to the presence of spaces with displacement ventilation and of naturally-ventilated spaces with open windows in other groups; the VOC concentration in rooms was lower; the ratio of indoor-to-outdoor PC was lower.
• in hybrid buildings:
unweighted and A-weighted low, mid and total sound-pressure levels were higher; rooms had greater NC levels; ventilation rates (ACH) were higher.
• 'green' buildings had:
lower unweighted low-frequency noise levels; lower total, unweighted sound-pressure levels; lower ventilation rates; lower fibre concentrations in the spaces (due to the absence of acoustic tile and carpets, and the low furniture density); higher ratios of indoor-to-outdoor PC; lower indoor temperatures (in winter).

As another part of the investigation, the impact of window status in naturally-ventilated rooms on the environmental conditions inside the spaces was investigated. Figure 1 shows the most significant correlations when the windows were open. In general:
• the unweighted and A-weighted levels of noise in all frequency bands and, therefore, total sound-pressure levels were noticeably increased;
• the magnitude of the indoor – 20% outdoor PC was greatly increased; this was due to the introduction of high volumes of unfiltered air into the spaces by opening the windows.

Moreover, it was observed that ventilation rate had a significant negative correlation with PC. In addition, VOC concentration was lower in spaces with lower ventilation rates (i.e. naturally-ventilated spaces, in general); this was

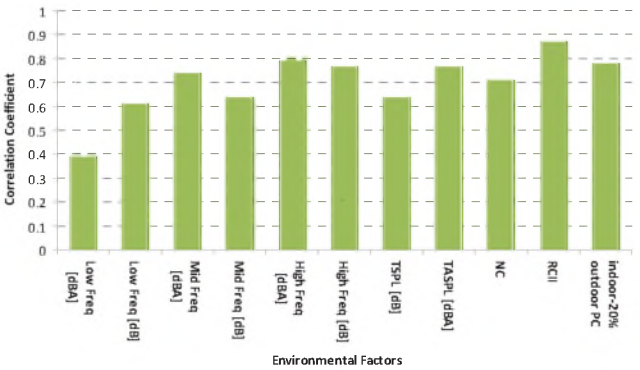

Figure 1. Influence of open windows on environmental factors in 'green' buildings

further confirmed by a high positive correlation between ventilation rate and VOC concentration.

CONCLUSION

The main conclusions of this pilot study are as follows:
• forced-air ventilation gives better IAQ, but higher HVAC noise levels; IAQ and noise level are directly related;
• in naturally-ventilated spaces with radiant ceiling slabs, lack of acoustic treatment gives lower fibre concentrations, but worse acoustical conditions;
• naturally-ventilated spaces have unsatisfactory ventilation quality but acceptable noise levels with the windows closed, and satisfactory ventilation quality but excessive noise levels with the windows open, even without significant external noise sources;
• naturally-ventilated spaces with few furnishings or sound-absorbing materials have higher IAQ;
• acoustical treatment can enhance acoustic quality, but worsens IAQ.

The results suggest that the optimum building design would use a mechanical-ventilation system designed according to current standards, with a ventilation rate conforming to current standards (to dilute contaminants), and with a carefully selected amount, type and location of acoustical treatment (use materials which generate less contaminants such as fibres, VOCs, etc.; use wall absorption in combination with radiant ceiling slabs).

REFERENCES

[1] ASHRAE Handbook of HVAC Applications, *Sound and Vibration* (ASHRAE, 2003).
[2] ANSI/ASA S12.60-2002, *American National Standard Acoustical Performance Criteria, Design Requirements, and Guidelines for School* (ANSI, 2002).
[3] ASHRAE Standard 62.1, Ventilation for Acceptable Indoor Air Quality (ASHRAE, 2004).
[4] WCB Laboratory Services, *Fibres in Air* (Workers Compensation Board, 1991).
[5] D.W. Bearg, *Indoor Air Quality and HVAC Systems* (Lewis, 1993).
[6] R.M. Hester, *Volatile Organic Compounds in the Atmosphere* (Cambridge: Royal Society of Chemistry, 1995).