ACOUSTICAL EVALUATION OF SIX 'GREEN' OFFICE BUILDINGS

Murray Hodgson[1], Rosamund Hyde[2], Blair Fulton[2] and Catherine Taylor-Hell[2]

[1] Acoustics & Noise Research Group, SOEH-MECH, University of British Columbia, 3rd Floor, 2206 East Mall, Vancouver, BC, Canada V6T 1Z3 [murray.hodgson@ubc.ca]

[2] Stantec Consulting Ltd., 1100 – 111 Dunsmuir Street, Vancouver, BC, Canada V6B 6A3

1. OBJECTIVES AND METHODOLOGY

The objective of this work was to evaluate six 'green' office buildings acoustically, to learn design lessons. It involved a meeting with designers, performing an occupant satisfaction survey (using a web-based survey developed by the Center for the Built Environment at the University of California at Berkley), analyzing the acoustical responses, walking through the building, planning acoustical measurements, performing and analyzing the acoustical measurements and considering the design implications of the results.

The study involved six very different nominally-'green' office buildings, all designed to prevailing sustainable-development principles, evaluated 1-5 years after occupancy. Descriptions can be found at www.sbtc.ca/index.cfm?bd=KBDet.cfm&id=60. All buildings had mainly glass façades for day-lighting, with sun shades and operable windows, and contained a mix of private and shared offices, and open-office cubicles.

2. MEASUREMENTS AND ACCEPTABILITY CRITERIA

The objective here was to use physical measurements to evaluate the acoustical environment, to explain the survey results which identified situations (workplaces and building conditions) of high and low occupant satisfaction. Workplaces at which measurements were performed were chosen to correspond to high and low occupant satisfaction. In general, these included desks in open-plan, shared and private offices, located in quiet and noisy areas, near and far from operable windows. Furthermore, measurements were made under building conditions expected to correspond to high and low satisfaction (windows or doors closed or open, quiet or noisy external source). Table 1 shows the four acoustical parameters that were measured. Also shown are the acceptability criteria used to evaluate each aspect of the acoustical environments in these office buildings.

Table 1. Acoustical measurement parameters and acceptability criteria.

Measurement parameter	Acceptability criterion
Background noise level, NC in dB	NC 30-35 in meeting, conference rooms NC 35-40 in workspaces
Reverberation time (mid-frequency), RT_{mid} in s	< 0.75 s for comfort, verbal communication
Speech Intelligibility Index, SII	> 0.75 for high speech intelligibility < 0.2 for high speech privacy
Noise Isolation, NIC in dB	NIC 35-40 for executive offices, conference rooms NIC 30-35 for general offices, meeting rooms

3. RESULTS

3.1 Designer meetings

Following are the main points relevant to acoustics learned from the designers at the meetings with them: LEED certification is often a goal that influences design; design often does not involve specialized acoustical expertise—acoustical consultants deal with 'special cases'; quantitative acoustical design targets are never set; designers are aware of acoustical issues; external noise (and pollution) concerns may rule out a fully-natural ventilation concept; 'green' buildings often have operable windows, which causes noise concerns if there's an external noise source; low noise levels resulting from absence of a forced-air system result in low speech privacy; client's wishes (e.g. for open-office design) may affect design; budget short-falls at the end of the project may affect acoustical quality; obtaining good noise isolation involves lined return-air ducts, upholstered furniture, acoustical ceilings, carpet, open-office partitions; some buildings are designed for any occupant; the internal 'fit-up' (e.g. acoustical treatments) is done later by contractors for tenants (on limited budgets); designers often believe their building is well designed, and is successful with occupants.

3.2 Occupant satisfaction surveys

The Berkley survey asks occupants to rate their general satisfaction with the building and with their workspace, with the office layout, with the office furnishings, with thermal comfort, air quality, lighting, acoustic quality and with the washrooms. Occupants rated quality on a scale of -3 (maximum dissatisfaction) to +3 (maximum satisfaction).

Figure 1 shows the results of the occupant satisfaction surveys done in five of the six buildings. Also shown (Ref) are the average scores from all buildings ('green' and non-'green') surveyed using the CBE survey. In general, satisfaction ratings were positive indicating satisfaction. Occupants were very satisfied with their buildings and workspaces, with the furnishings, office layouts, cleanliness and maintenance and with the washrooms. They were generally very satisfied with the lighting, and some-

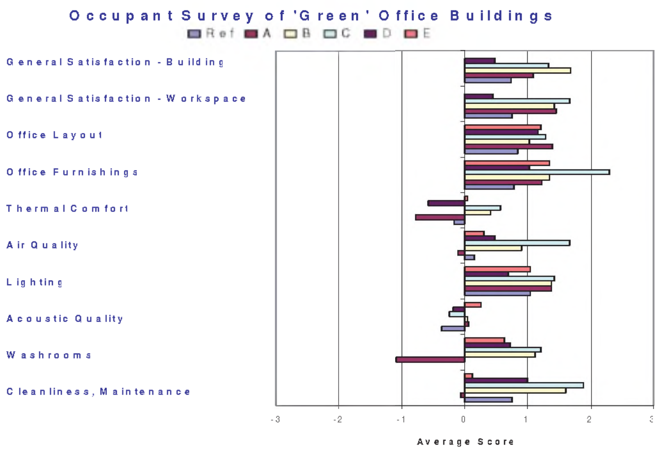

Figure 1. Occupant satisfaction survey results for five 'green' office buildings.

what satisfied with air quality. Satisfaction with thermal comfort varied from somewhat satisfied to somewhat dissatisfied. Occupants were generally dissatisfied with the acoustical environment, which often received the lowest rating. Speech privacy is the biggest acoustical issue.

3.3 Acoustical measurements

Following are the main results of the acoustical measurements:

• Background Noise Level: NC 26-34 (unoccupied, natural ventilation); NC 35-42 (unoccupied, forced-air ventilation); NC 45-60 (external noise, windows open); NC 40-60 (occupied);

• Reverberation Time: open-office areas: 0.6-1.0 s (low absorption); 0.2-0.4 s (high absorption); private offices: 0.4-0.7 s (low absorption); 0.2-0.4 s (high absorption); hallways, atriums: 0.9-2.4 s;

• Speech Intelligibility (private office, across desk, casual voice): 0.3-0.6 (forced-air ventilation, low absorption); 0.7 to 0.8 (natural ventilation, high absorption);

• Speech Privacy. Between open-office cubicles, casual voice): 0.3-0.6 (forced-air ventilation, low absorption); 0.7-0.8 (natural ventilation, high absorption). Outside-inside private office (door open, casual voice)=0.7;

• Noise Isolation: into closed offices = NIC 25-30 (door closed); = NIC 9-15 (door open); between work areas = NIC 7-20.

3.4 Design implications

The main acoustical design implications of the results related to low background noise levels, inadequate speech privacy, excessive reverberation, inadequate noise isolation between workplaces in open and shared work areas, and inadequate internal and external wall isolation. Following are details as they relate to 'green'-building issues:

• since LEED virtually ignores acoustics, a building designed to obtain LEED certification is unlikely to have adequate attention paid to the acoustical environment;

• 'green' buildings often are designed to have natural/displacement ventilation systems; these can affect the acoustical environment beneficially or detrimentally, resulting in low background-noise levels and low noise isolation; however, forced-air ventilation can figure in 'green'-building design;

• many 'green' buildings have little sound-absorption; this affects the acoustical environment detrimentally, resulting in excessive reverberation, low acoustical privacy and inadequate attenuation of sound propagating through the building; however, beneficial sound-absorbing materials can figure in 'green'-building design;

• if a 'green' building, designed with a ventilation system relying on operable windows, is located next to a significant noise source, noise problems are likely, especially if the windows open on the source side;

• a 'green' building designed to rely on a natural/ displacement ventilation system, and with transparent envelope for day-lighting, may overheat on hot, sunny days, forcing occupants to open windows and office doors, resulting in excessive noise and low speech privacy;

• background-noise levels in a 'green' building with full or partial natural-ventilation system may be lower than as expected in a conventional building with a forced-air system. These low levels may make it more difficult to achieve adequate speech privacy;

• a 'green' building designed to rely on a displacement ventilation system usually involves air-transfer openings and/or ducts in partitions. These significantly reduce noise isolation between areas, even when treated acoustically.

4. DISCUSSION AND CONCLUSION

The acoustical environment is often judged the least satisfactory aspect of 'green' office buildings by the occupants. They are dissatisfied with excessive noise and poor speech privacy, and consider that the acoustical environment does not enhance their ability to work (i.e. productivity). Speech privacy is often the biggest concern.

The results of this study suggest that improving acoustical environments in 'green' buildings fundamentally requires good acoustical design – that is, the application in design of existing knowledge, with input from an acoustical specialist from the beginning of the design process. This knowledge relates to site selection and building orientation, to the design of the external envelope and penetrations in it, to the building layout and internal partitions, to the design of the HVAC system, to the appropriate dimensioning of spaces, and to the amount and location of sound-absorbing treatments. For a satisfactory acoustical environment, the advice of the acoustical specialist must be followed, and the budgetary resources made available for it to be implemented.

ACKNOWLEDGMENT

The authors gratefully acknowledge the support of the EcoSmart Foundation, Vancouver, which is supported by the Government of Canada.