SOUND TRANSMISSION LOSS OF EXTENSIVE GREEN ROOFS - FIELD TEST RESULTS

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1. INTRODUCTION

Green roofs have the potential to provide excellent external/internal sound isolation due to their high mass, low stiffness and damping effect and, through surface absorption, to reduce noise pollution in the community from aircraft, elevated transit systems, industrial sites and noise build-up in urban areas. This paper reviews the acoustical characteristics and the potential contributions of green roofs to the acoustical environment, investigates applicable literature and sound transmission theory and reports on new empirical findings on the transmission loss of green roofs. A diffuse to free field intensity level measurement methodology was developed to obtain the presented results and for use in a future field test facility.

Current construction practices, driven in part by sustainable building rating programs, have led to an increased use of lightweight metal roof assemblies and a decreased use of ceilings. Green roofs can provide a higher transmission loss than the additional ceiling element and improve transmission loss throughout the full architectural frequency range, specifically desirable in residential occupancies developed below aircraft flight paths. The field testing conducted on two 33 m^2 low profile extensive green roofs indicated an increase of 5 to 13 dB in transmission loss over the low and mid frequency range (50 Hz to 2000 Hz), and 2 dB to 8 dB increase in transmission loss in the higher frequency range relative to the transmission loss of a reference roof.

2. GREEN ROOFS

2.1 Acoustical contribution and benefits

Green roofs have the potential to provide excellent external/internal sound isolation due to their high mass and low stiffness; through surface absorption, green roofs have the potential to reduce noise pollution in the community from elevated transit systems, industrial sites and noise build-up in urban areas. The sound transmission characteristics of a green roof are governed by the multiple layers of fluid, solid, and poro-elastic materials that comprise the full profile of the vegetated roof system. This research is initially focused on flat, nominally sloped (2% to 4%) extensive green roofs. Extensive green roof systems are comprised of the roof deck, vapour barrier, insulation, waterproofing membrane, root barrier, water reservoir/ drainage layer, filter fabric, substrate and drought-tolerant plant species. Extensive green roofs have a shallow substrate profile, 40 mm to 150 mm thick, and are installed on both conventional and protected membrane roof systems—often installed on buildings without significant cost for additional structural loading. Significant research has determined that green roofs can reduce stormwater runoff and lower a building's energy demand for cooling/heating through improved thermal performance (1). Green roofs can provide mitigation of unacceptable noise levels that affect the health, safety and well-being of the urban population; however, the acoustical benefits of green roof technologies have not yet been investigated.

2.2 Literature Review

The review of empirical findings on the TL of roofs highlights three summarizing concepts. First, the use of additional materials to mass load and add damping to the roof can virtually eliminate the coincidence effect and increase transmission loss at low frequencies (2, 3, 4). Second, in the absence of green roof technology, increased TL was achieved by the addition of a ceiling; this addition to the roof assembly increased TL only in the mid and high frequency ranges, not in the low frequency range of potentially disturbing noise from aircraft (5, 6). Third, two reports on pre-cultivated green roof mats provided evidence that the moisture content of the substrate and the water retention mat is a physical property that affects the acoustical characteristics (7,8).

It is suspected that transmission losses in the layer of the substrate will be of major importance. Findings support the hypothesis that soil texture affects the attenuation of sound as it passes through the depth of the soil (9). The physical properties most prevalent in the research include particle size distribution, bulk density and porosity, flow resistivity, and tortuosity; soil conditions of moisture and compaction are variables affecting the acoustic characteristics (10). The findings from the literature support the investigation of sound transmission loss as a function of the plant species on the green roof. The vegetated root interface with the soil has been identified as affecting the normal specific impedance (12).

3. METHOD

A reverse testing method initiated by Mulholand and Sharp (1978), proved to be very useful as a strategy for developing a methodology for this research and a future field test facility (12). The ISO 15186 series indoor to outdoor method (13), propagating sound from an interior diffuse field to an exterior free field was adopted. The ISO 15186 standard uses an intensity approach to evaluate the transmitted acoustic intensity radiated by the element under test while the incident intensity is deduced from the average sound pressure level in the source room. Sound transmission loss is calculated as:

$$TL = \left[L_{p1} - 6 + 10\lg\left(\frac{S}{S_0}\right)\right] - \left[\overline{L}_{In} + 10\lg\left(\frac{S_M}{S_0}\right)\right]$$

L_{p1} is the average sound pressure level in the source room
S is the area of the separating partition under test
L_{In} is the average normal sound intensity level over the measurement surfaces
S_M is the total area of the measurement surfaces
S_0 =1 m^2.

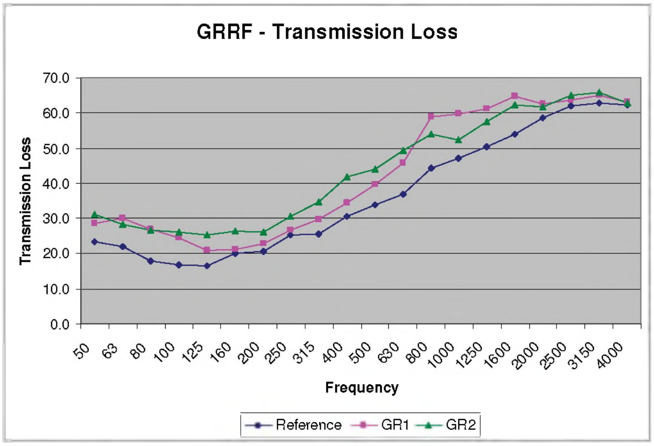

Fig. 1. Measured transmission losses of three roofs.

The Green Roof Research Facility at the BCIT Centre for the Advancement of Green Roof Technology has three independent research roofs originally commissioned in 2003 for the evaluation of stormwater runoff characteristics and thermal performance of green roofs. One roof is a conventional system which acts as a reference roof test specimen, the other two roofs (GR1 and GR2) have the same roof system to the top of the membrane as the reference roof, plus identical green roof components, differing only by the depth of substrate. GR1 has 75 mm and GR2 has 150 mm of substrate. The planting was consistent in its establishment at the time of sound transmission evaluation. Potential sound flanking paths through roof drains, which lead to internal meters, and the roof jack conduits, containing the thermal performance and weather station wiring, were eliminated with sand filled bags and 12 mm steel plates. There is no additional ceiling in the research facility.

An array of five loudspeakers was used in the GRRF interior to create an approximately diffuse sound field. The average sound pressure level was 93 dB generated in each 1/3 octave band. For calculation of the TL the space averaged sound pressure was measured below each of the three roofs. The radiating intensity was measured at 12 discrete points on each of the three roofs.

4. RESULTS

Figure 1 illustrates the resulting transmission loss/frequency curves. All three roofs exhibited an increase in TL with increasing frequency. There is a dip in TL of the reference roof at 125 Hz; however, it is not conclusive whether this is due to the coincidence effect. GR1 (75 mm substrate) exhibited inconsistent increases in TL over the frequency range. The consistent increase in TL of GR2 (150 mm substrate) is illustrated in the TL curve above that of the reference roof. The substrate and green roof materials increased the TL over the low-mid frequency range of 50 Hz to 2000 Hz, by 5 dB to 13 dB, and in the higher frequency range by 2 dB to 8 dB. This is a significant decrease in low and mid frequency sound level transmission; the green roof then provides the opportunity to eliminate the need for ceiling installations for the purpose of increase sound transmission loss. Comparable sound transmission loss through the addition of a ceiling and insulation may not be attainable at low frequencies up to 125 Hz.

5. CONCLUSION

Existing sound transmission algorithms do not adequately predict TL of light-weight roof system or green roofs, nor describe the potential effect of moisture content of the substrate. The sound energy is dissipated in the substrate and provides a mass loading and damping effect on to the light-weight roof deck. Current construction practices, driven in part by sustainable building rating programs, have led to an increased use of lightweight metal roof assemblies and a decreased use of ceilings. Green roofs will provide a higher TL than the additional ceiling element and improve TL throughout the full architectural frequency range, specifically desirable in residential and institutional occupancies developed below aircraft flight paths.

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