Experimental analysis of the noise shielding by a green roof in response to rainfall

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ABSTRACT

A vegetated roof top (green roof) was shown to be the most promising building envelope greening measure to achieve quietness at a shielded side. In addition, such a measure comes with many ecological and economic benefits in addition to noise reduction. Noise abatement by green roofs has been assessed extensively before by detailed full-wave numerical simulations, by in-situ and full-scale laboratory diffraction experiments, and by characterizing the acoustic properties of the materials involved. In general, the absorption coefficient of any porous material is negatively affected by the presence of water. To assess the influence of rainfall on the acoustic performance of a green roof, a controlled in-situ diffraction experiment has been set up. The measurements, lasting for about 1.5 months, show a decrease in shielding with increasing moisture content, especially in the frequency range between 315 Hz and 1250 Hz. The difference in shielding between dry and (near) saturated state may amount up to 8 dB. Outside this frequency interval, diffraction over the green roof was hardly influenced by the volumetric water content of the substrate.

Keywords: building envelope design, green roofs, diffraction, meteorological effects I-INCE Classification of Subjects Number(s): 24.3, 24.4, 51.2

1. INTRODUCTION

The environmental, ecological and economic benefits of green roofs are numerous (see following review articles (1,2,3,4) to get an overview). Also the noise reduction has been recognized as an additional benefit regarding building performance. Scientific research points e.g. at the augmented acoustic roof insulation provided by a green roof (5,6). Most relevant, however, is the ability of green roofs to reduce sound waves propagating over buildings (7,8,9,10). In contrast to common rigid building envelopes, the typical (highly) porous substrates used for vegetated roof tops help making a shielded facade really silent, on condition that the dominant sound path interacts with the green roof. This effect has been shown by numerical modeling (7,8), in-situ experiments (9) and by measurements under controlled laboratory conditions (10). Making at least one side of buildings silent has become an important goal in European city noise policy in the view of the so-called “quiet side effect” (see e.g. Ref. 11).

The presence of water in any porous materials deteriorates its sound absorbing properties. It is therefore expected that green roofs will perform worse after rainfall events. Impedance tube measurements indeed showed a decrease in absorption coefficient (at normal incidence) with increasing moisture content (12). However, the impact of rainfall on the acoustic shielding of a green roof in real-life conditions remains a question and is the subject of the current research.

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2. EXPERIMENTAL SETUP

2.1 Site Description

The measurements were conducted near the edge of a rectangular building equipped with an extensive green roof (Kontich, Belgium). A detailed cross-section with indication of the dimensions is depicted in Figure 1. Propagation towards microphone 2 (M2) involved 15.3 m interaction length with the green roof. The building under study has an elevated roof edge.

The extensive green roof under study consists of a synthetic drainage fabric (roof protection membrane, water evacuation layer, and filter membrane; in total 8 mm thick), a mineral substrate layer (7 cm thick), and a vegetation layer containing various sedum species (coverage near 65 % in the section under study, about 3 cm thick).

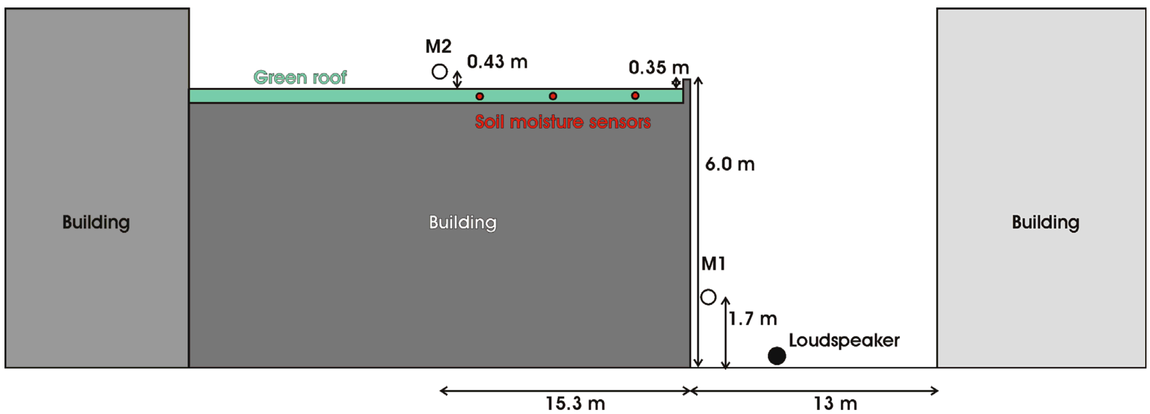

Figure 1 – Schematic representation of the experimental site (not true to scale) and positioning of instrumentation.

2.2 Measurement procedure

The sound pressure level difference between the reference microphone (M1) and a second microphone (M2) positioned at low height above the green roof is continuously monitored over a period of 46 days. The variation in attenuation between these microphones, as influenced by the changing meteorological conditions, is the focus of this experiment. An outdoor loudspeaker is used to fully control the sonic environment – at regular times, test signals were emitted. Three soil moisture sensors were buried in the substrate, and on-site meteorological measurements were made (relative humidity, air temperature and rainfall intensity).

Type-1 ½" condenser microphone capsules and pre-amplifiers were used, with weather proof outdoor units. The signal emission and recordings were time-synchronized. A dedicated signal processing methodology was developed, consisting of a cross-correlation procedure, time-windowing and adequate averaging. A detailed description of the site, instrumentation and signal processing can be found in Ref. 13.

3. EXPERIMENTAL RESULTS

During the measurement period the total amount of rainfall was 23.2 mm, and sufficient variation in the substrate's volumetric water content (VWC) was measured (ranging from 0.09 m^3/m^3 to 0.29 m^3/m^3) due to natural precipitation.

Since the experiment was conducted in a non-silent environment, and given the limitations on the emitted source power, measurements with a signal-to-noise ratio below 7.5 dB (in the frequency range from 100 Hz to 3.15 kHz) were removed from the dataset afterwards. The moments with rainfall were not retained too.

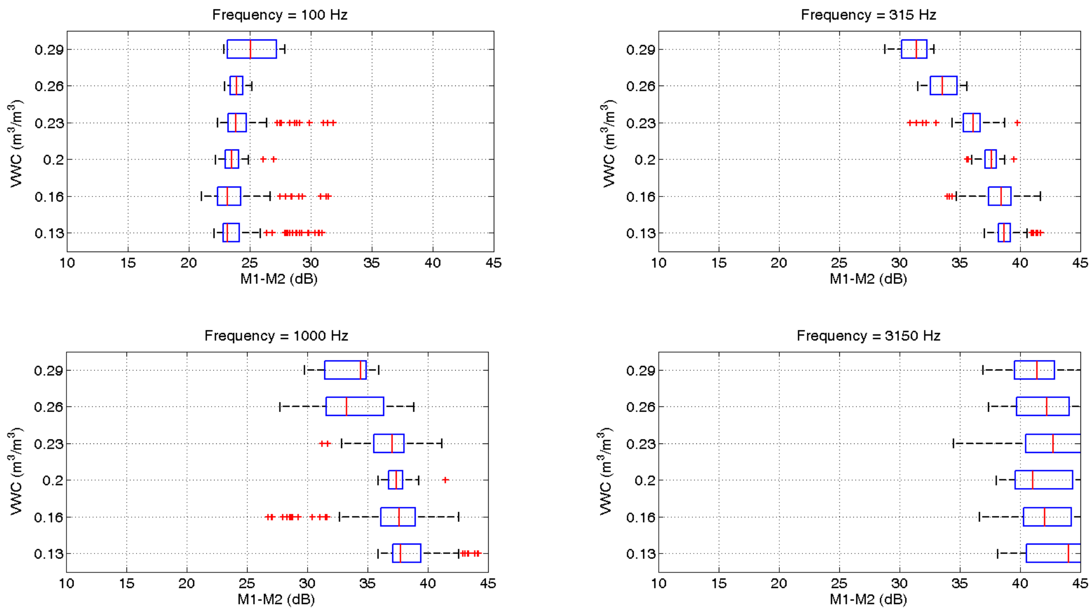

Figure 2 – Boxplots showing the sound attenuation (M1-M2) between the two microphones in function of substrate volumetric water content (VWC) at 4 selected one-third octave bands.

Moisture content of the substrate was identified as the major contribution to the variation in attenuation between both microphones. The boxplots in Figure 2 show the effect of the VWC, expressed in 6 classes, on the sound attenuation for four 1/3-octave band considered in the experiment. Below 250 Hz and above 1.6 kHz, the effect of the substrate moisture content on the attenuation is limited. Between 315 Hz and 1250 Hz, the median of the sound attenuation lowers significantly with increasing the volumetric water content; so wet substrates perform significantly worse in this frequency range. The effects are most pronounced at 315 Hz and 400 Hz, where the difference in attenuation for the range of VWCs measured approaches 8 dB.

4. CONCLUSIONS AND DISCUSSION

Sound diffracting over a green roof showed to be sensitive to the substrate moisture content in a specific frequency range, roughly between 315 Hz and 1250 Hz.

The limited effect at low frequencies can be explained by the fact that the absorption coefficient of such substrates is limited, even under dry conditions, and the presence of water thus has no big impact. At higher frequencies, characterized by short wavelengths, the (elevated) roof edge is expected to play an important role. The latter allows diffracted sound to propagate more or less in a straight line from the roof edge towards the microphone on the green roof. Intermediate frequencies, on the other hand do interact with the green roof substrate, while absorption coefficients under dry condition are quite high. In case of higher moisture contents water fills pores and granules swell, limiting the available space for sound entering the substrate. The latter is essential to benefit from absorption of acoustic energy.

Note that sufficient water retention in green roofs is important, often being the main motive for placing a green roof on a building (see e.g. Ref. 2). As a result, designs for increased water retention might be non-optimal for both the acoustical absorption and thermal insulation (see e.g. Ref. 3). Additional calculations (see Ref. 13), based on the current experimental data, showed that the variation in acoustic shielding for A-weighted total road traffic noise is nevertheless limited, given the fact that moisture effects, albeit pronounced, operate in a specific sound frequency range.

ACKNOWLEDGEMENTS

The authors would like to thank Philip Bruon, business unit manager of De Boer Green Roof Solutions, and the people from Main d'Or for kindly allowing us to use their building as test location and for practical assistance whenever needed.

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