大阪 inter.noise 2011
Osaka Japan September 4-7

Sound reduction by vegetated roof tops (green roofs): a measurement campaign

Timothy Van Renterghem[1] and Dick Botteldooren[2]

[1-2]Department of Information Technology, Ghent University, Sint-Pietersnieuwstraat 41, 9000 Gent, Belgium

ABSTRACT

Green roofs (vegetated roofs tops) have many ecological and economic advantages. Noise reduction is one of them. Measurements of sound diffraction over buildings were performed in 5 cases, just before and just after the placement of different types of extensive green roofs. The source and receiver configuration was kept the same in each case, allowing a direct estimate of the sound reducing effect. Measurements showed that green roofs might lead to consistent and significant sound reduction at shielded receivers relative to common non-green roof finishing. Improvements up to 10 dB were found in a wide frequency range, under dry conditions. It was further shown that predicting the green roof noise reducing effect is difficult, caused by the multi-layered build-up of a typical green roof and the shifts in the interference pattern relative to rigid roofs, especially at elevated receivers.

Keywords: Green roofs, sound propagation, sound diffraction, measurements

1. INTRODUCTION

Green roofs have many ecological and economic advantages, and also its noise reducing potential has been recently identified. While increased sound insulation of the roof system by the presence of a green roof has been measured [1], most practical applications related to environmental noise deal with reducing the intensity of diffracting sound waves over roofs [2][3][4]. Green roofs have (highly) porous substrates and therefore allow noise reduction. This effect is enhanced given the fact that sound propagates most often parallel to the roof in practical situations (shearing waves).

Numerical simulations presented in Refs. [2] and [3] show the high noise reducing potential of green roofs, compared to rigid roofs which are most often encountered. An example of a useful application of a green roof to achieve noise reduction is a building extension facing a nearby road. Positive effects were also predicted in a typical street canyon setup, leading to increased quietness in shielded courtyards or at non-directly exposed façades.

Experimental data of sound propagation over real green-roofed buildings is lacking. In this study, in-situ measurements of the effect of flat, extensive green roofs are presented. It is intended to show what can be expected from typical green roof practice (not optimized from the viewpoint of noise reduction) at various building configurations. Measurements were performed just before and just after placement of the green roof, with an identical source-receiver setup. In this way, the green roof effect can be directly estimated. Five cases have been selected where such measurements were possible.

2. MEASUREMENT METHODOLOGY

2.1 Instrumentation and data processing

An alarm gun (with blanks) was used as acoustic source, producing high sound power levels leading to easily identifiable peaks even at highly shielded locations. Furthermore, the signal-to-noise ratio was shown to be sufficient over the frequency range between 50 Hz and 10 kHz in the measurements performed.

[1] timothy.van.renterghem@intec.ugent.be
[2] dick.botteldooren@intec.ugent.be

The reproducibility of successive shots produced by the gun was checked in a full anechoic chamber. Five shots were released at close distance from the microphone. The standard deviation in function of sound frequency is shown in Fig. 1. Both at low and high frequencies, the standard deviations are near 1.5-2 dB. For the intermediate frequencies, this value is between 0.5 dB and 1 dB. Given the rather good reproducibility, no reference measurements have been included to capture possible variations in the emitted source power level in the "before" and "after" measurement. Five repetitions were considered to be sufficient.

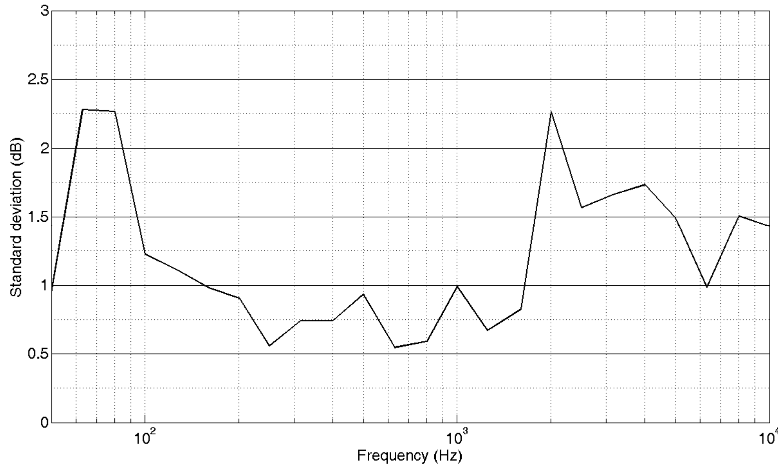

Figure 1 – Standard deviation in function of sound frequency in case of 5 successive shots as measured in an anechoic chamber.

The logging was performed with a Svantek 959 portable device, connected to a pre-amplifier and a ½" electret microphone capsule (Microtech MK 250 B). The saturation level exceeds 140 dB (at 1 kHz) which was sufficiently high for the envisaged application, keeping in mind the high source powers emitted. Before each measurement, a calibration was performed with a Bruel & Kjaer 124 dB pistonphone, producing a pure tone near 250 Hz. Results were logged as 1/3 octave bands integrated over 10-ms periods. The peaks corresponding to the repeated shots were identified afterwards based on the time series of the total sound pressure level as illustrated in Fig. 2. After identification of the correct times, the spectra were energetically averaged over the duration of each shot, and then linearly averaged over the 5 repetitions.

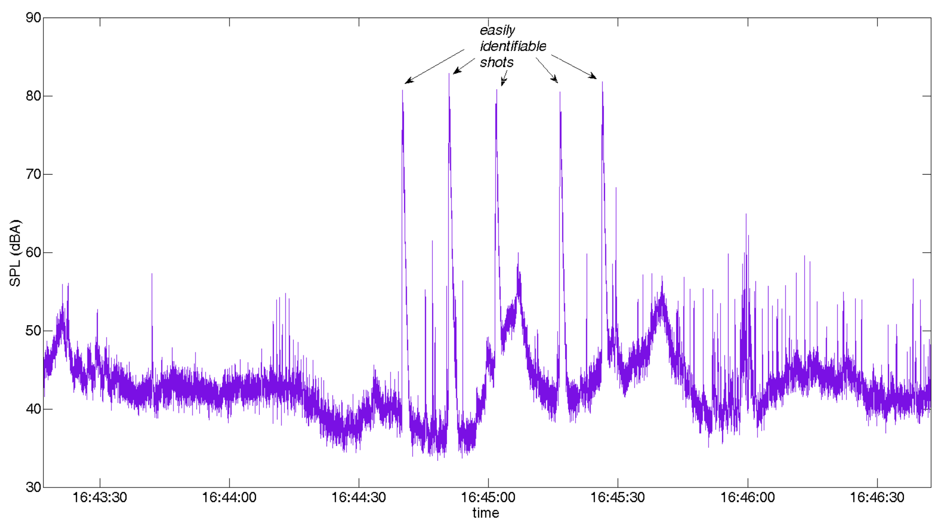

Figure 2 – Example of measured time series at the microphone.

2.2 Description of test cases

For cases 1 to 3, a single diffraction is needed for sound propagating from source to receiver. Such cases are typical for a building extension and a receiver located near a façade/window as illustrated in Fig. 3. Cases 4 and 5 involve double diffraction towards a completely shielded receiver (see Fig. 3). These two types represent situations where positive effects of green roofs can be expected as shown with the numerical simulations reported in Refs. [2] and [3].

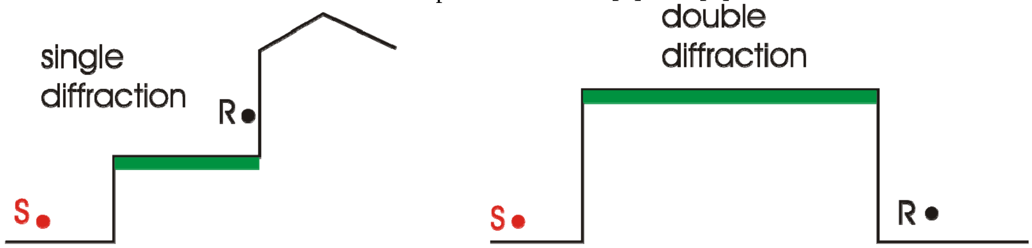

Figure 3 – Schematic overview of single diffraction and double diffraction cases (S=source, R=receiver).

In cases 1 to 3, the lengths of the green roofs along the shortest propagation path are 8 m, 4 m and 4.5 m, respectively. The substrate depths are 20-30 mm, 50-60 mm and 180 mm, respectively. In cases 4 and 5, the distance propagated over the green roof is near 25 m. In case 4, substrate depth is only 20-30 mm, while it is near 80 mm in case 5. Measurements were performed mainly just after placement of the green roof, after dry periods. The layer build-up (drainage layer, water retention layer, type of substrate, etc.) was quite different in the 5 cases considered. Vegetation cover ranged from 0% to 100%. A more detailed description of the different cases can be found in Ref. [5].

3. RESULTS AND DISCUSSION

3.1 Single diffraction cases

In Fig. 4, the green roof improvement (i.e. the reduction in sound pressure level by the presence of the green roof relative to a common non-vegetated roof finishing) is depicted. Rather strong effects are found over wide frequency ranges, although the short propagation distances. At some frequency bands, negative effects are observed. The latter is more pronounced for higher receiver positions (see Ref. [5]), caused by shifts in interference pattern due to changes in roof cover. For the longer propagation paths interacting with the green roof (compare case 1 to case 2 or 3), a more consistent green roof improvement in function of frequency is found. Case 3 is characterized by a thick substrate layer of 180 mm, yielding noise reductions exceeding 10 dB in the frequency range between 300 Hz and 1 kHz.

Below 100 Hz, no significant effects are measured in any case. Also above 5 kHz, there is no net effect by the presence of the green roof in the single diffraction cases considered.

The results show rather complex behavior and prediction does not seem straightforward. The exact layer build-up is quite different among the tested cases and is expected to play an important role.

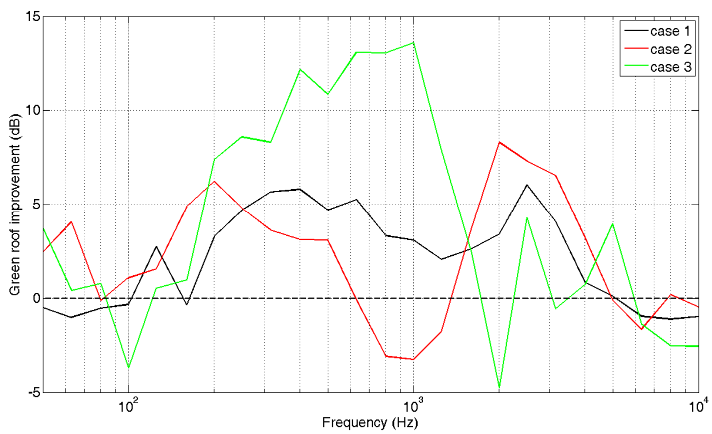

Figure 4 – Green roof improvement for the single diffraction cases.

3.2 Double diffraction cases

For the double diffraction cases (cases 4 and 5), receivers are now fully in the acoustic shadow zone of the building, and the interaction path between the green roof and the shearing waves is much longer than in the single diffraction cases. Results are shown in Fig. 5. In case 4, consequent and rather uniform effects are observed from 300 Hz till 10 kHz, with green roof improvements up to 5 dB. In this case, the substrate thickness was very limited (prefabricated green roof tiles). In case 5, strong effects are observed between 100 Hz and 800 Hz, but at higher frequencies effects become very limited. The substrate depth in case 5 is much larger than in case 4.

The continued positive effect above 3-4 kHz in case 4 could be caused by the presence of vegetation, leading to scattering of sound waves diffracting over the roof. Strong scattering can be expected from these frequencies on. In case 5, vegetation was absent at the time of the measurement. The amount of data presented here is however insufficient to sort out the effect of the presence of vegetation on green roof substrates. The influence of receiver height (see Ref. [5]) is less pronounced in the double diffraction cases compared to the single diffraction cases.

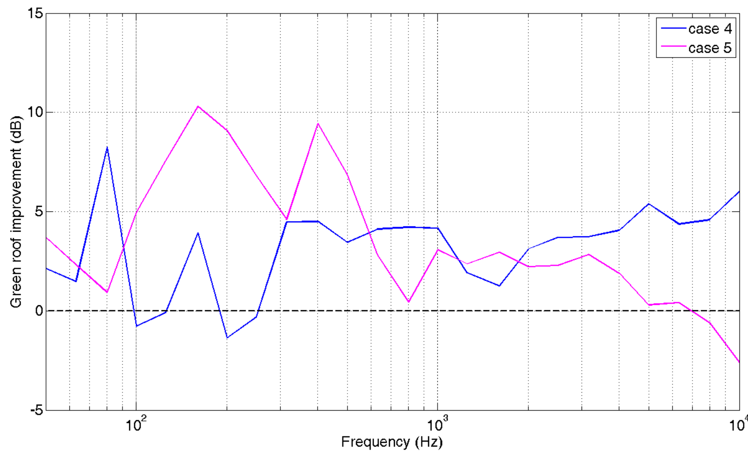

Figure 5 – Green roof improvement for the double diffraction cases

4. CONCLUSIONS

The noise reducing effect of green roofs has been confirmed by means of in-situ diffraction measurements. Important noise reductions were measured compared to common (non-greened) roof finishing, both for single and double diffraction cases. Consistent positive effects over wide frequency ranges are mainly present in case of double diffraction cases. The multi-layered build-up of green roofs leads to complex acoustic behavior. It has to be noted that all measurements were performed at dry green roofs. The green roof improvements are expected to be significantly lower after rainfall events.

REFERENCES

[1] J. Kang, H. Huang and J. Sorrill, “Experimental study of the sound insulation of semi-extensive green roofs,” Proc. INTER-NOISE 2009 (2009).
[2] T. Van Renterghem and D. Botteldooren, “Numerical evaluation of sound propagating over green roofs,” J. Sound Vib. 317 (3-5) 781-799 (2008).
[3] T. Van Renterghem and D. Botteldooren, “Reducing the acoustical facade load from road traffic with green roofs,” Build. Env. 44 (5) 1081-1087 (2009).
[4] H. Yang, M. Choi and J. Kang, “Laboratory study of the effects of green roof systems on noise reduction at street levels for diffracted sound,” Proc. INTER-NOISE 2010 (2010).
[5] T. Van Renterghem and D. Botteldooren, “In-situ measurements of sound propagating over extensive green roofs,” Build. Env. 46 (3) 729-738 (2011).