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Acoustic effects of green roof systems on a low-profiled structure at street level

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ABSTRACT

Green roof systems have become commonly used in urban spaces due to numerous ecological and environmental benefits. Various kinds of green roof systems can also be used at street level, on the top of underground car parks, for example. In this situation, it is important to systematically examine the acoustic effects of designable parameters, especially for diffracted sound waves. In this study, therefore, a series of measurements were carried out in a semi-anechoic chamber using green roof systems which consist of the Zinco and limestone-based substrates. They were placed on a box with a height of 1200 mm. Numerical simulations were also carried out for selected cases. Studied parameters included the area, depth, type and position of the green roof system, and the type of vegetation. The results show that such green roof systems can reduce SPL effectively at the receiver side of the boxes. Within the ranges of the parameters considered, the effect of the depth and type of substrates is relatively small compared to that of the overall configurations of the system. By adding pruned leaves on the green roof there is only a small noise reduction above 4 kHz but optimised absorption treatment could bring up to 4 dB(A) noise reduction for traffic noise. The position of the green roof system affects the pattern of SPL reduction differently at different frequency ranges.

1. Introduction

Along with the strong movement towards sustainable urban environments, green roof systems have become widely used in urban spaces since they have numerous ecological and environmental advantages. For example, green roof systems can reduce storm water runoff, increase urban bio-diversity, and mitigate the urban heat island and air pollution [1–6].

In terms of acoustic benefits, green roof systems have been regarded as an effective structure to reduce noise pollution in urban spaces arising from road, rail and air traffic [7]. Such sustainable materials using natural means can also contribute to the reduction of environmental impact as well as the improvement of soundscapes [8,9]. In street canyons and courtyards, the amount of sound energy propagating over rooftops from noisy sides to quite sides is mainly determined by the height, width and shape of buildings [10–13]. In this case, green roof systems on the top of buildings can act as absorbers especially for diffracted sound waves between parallel streets and for that, parametric studies have been carried out [14–17], showing that green roof systems are effective on noise mitigation, and therefore creating quiet sides. Moreover, it has been shown that green roofs can be used to effectively increase the sound insulation of light-weight roof structures [18].

At street level, various kinds of green roof systems can also be used, for example, on the top of underground car parking spaces. In particular, semi-extensive green roof systems, which support low-growing, tough, and drought-resistant vegetation [7], can be installed in many places instead of grass land at street level due to various reasons such as better visual effects and maintenance. There is a potential that green roof systems on low-profiled structures can be developed to an innovative and sustainable low barrier using natural elements for reducing traffic noise [19,20]. However, studies on the use of green roof systems at street level have not been reported yet.

The aim of this study is therefore to explore systematically the effects of various designable parameters of green roof systems at street level on noise reduction. A series of measurements have been carried out in a semi-anechoic chamber using green roof systems which consist of the Zinco (brand name of green roof substrate) and limestone-based substrates. They are placed on a box with a height

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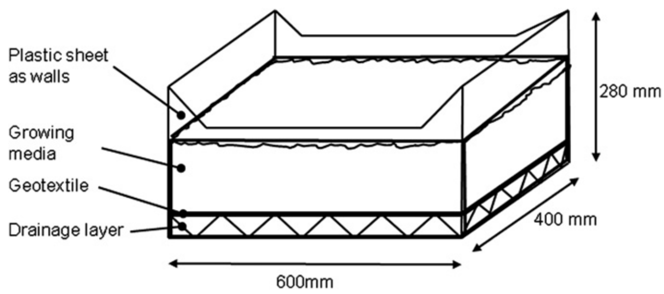

Fig. 1. Components of a green roof tray.

Table 1
Product data of the sedum carpet and roof garden substrate used for Zinco substrate[a].

	Sedum carpet substrate	Roof garden substrate
Granules of <0.063 mm ∅	≤7%	≤20%
Granules of <4 mm ∅	≥25%	–
Organic content	≤4%	–
Porosity	63%	64%
Dry weight	980 kg/m^3	930 kg/m^3
Saturated weight	1240 kg/m^3	1400 kg/m^3
Maximum water capacity	25%	46%
Air content at saturation	38%	18%
Water permeability	≥0.1 cm/s	≥0.034 cm/s

[a] Source: Alumasc product data sheet.

of 1200 mm. Numerical simulations have also been carried out for selected cases. Studied parameters include the structure, area, depth, type and position of the green roof system, and the type of vegetation.

2. Methodology

2.1. Physical properties of the green roof systems

The green roof systems in this experiment were comprised of 600 mm × 400 mm × 280 mm (outer dimension) plastic trays.

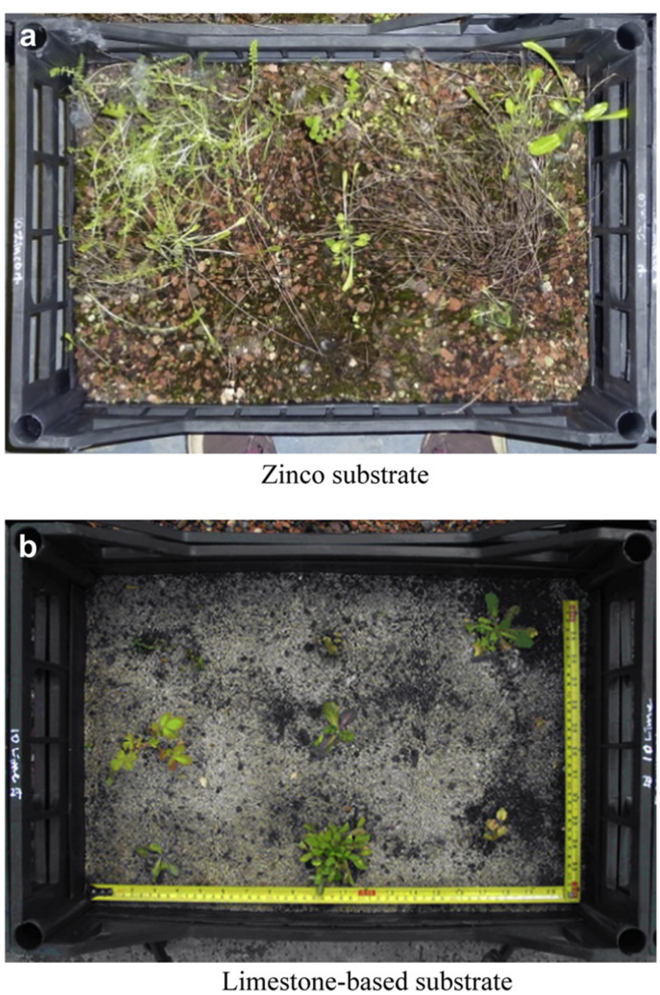

Fig. 2. Zinco and limestone-based substrates used in the experiment.

Fig. 1 shows the components of the tray: a 30 mm drainage layer on the bottom and plastic panels as walls; a geotextile membrane filter layer to prevent obstruction of the drainage layer by small particles of growing media; and growing media of Zinco or limestone-based substrates.

In Fig. 2 Zinco and limestone-based substrates used in this experiment are shown. The Zinco substrate was a mixture of Zinco sedum carpet substrate and Zinco roof garden substrate, with a ratio of 1:1. Table 1 describes detailed product data for these components. The limestone-based substrate consists of 60% limestone (<3.35 mm particle size), 20% loam and 20% organic matter. The physical properties of Zinco and limestone-based substrates are given in Table 2.

In the experiment, 3 different substrate conditions were used: Zinco substrate with depths of 50 mm and 100 mm, and limestone-based substrate with a depth of 100 mm. For Zinco substrate, 20 trays for each depth condition were used. The mean weight for each tray of Zinco substrate with depths of 50 mm and 100 mm was recorded as 11.3 kg and 24.0 kg, respectively. For the limestone-based substrate, 18 trays with a mean weight of 29.1 kg per tray were used. In the spring of 2007, each tray was planted with 9 native forbs individuals originating from calcareous grassland habitat. However, few plants with 0–10% vegetation coverage for each tray remained due to unfavourable planting season. Therefore, the substrate dominates the effect of SPL (sound pressure level) attenuation.

To examine the acoustic effect of vegetation growing on green roof systems, pruned fresh leaves (*Buxus sempervirens*) and 100% polyester cotton were applied, respectively, as shown in Fig. 3. Here the polyester cotton, with a mean weight of 159.5 g per tray, was used to simulate an extreme condition in terms of sound absorption by vegetation. The pruned *B. sempervirens*, for simulating dense leaf conditions on green roof systems (although it is noted that the loose leaves and twigs could lead to some vibration-related effects such as free vibration), have leaf sizes ranging from 8 mm to 30 mm long and 5 mm to 13 mm wide, and mean weight of 606.8 g per tray. For both pruned fresh leaves and polyester cotton, the filling depth in the trays was 120 mm approximately, representing

Table 2
Physical properties of the Zinco and limestone-based substrates.

	Loose bulk density (g/cm^3)	Bulk density at saturation (g/cm^3)	Increase in bulk density (%)	Air filled porosity (%)	Water holding capacity (%)
Zinco	1.02	1.26	23.5	33.5	26.6
Limestone-based	1.43	1.80	26.2	12.0	29.8