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Evaluation of green walls as a passive acoustic insulation system for buildings

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ABSTRACT

Greenery on buildings is being consolidated as an interesting way to improve the quality of life in urban environments. Among the benefits that are associated with greenery systems for buildings, such as energy savings, biodiversity support, and storm-water control, there is also noise attenuation. Despite the fact that green walls are one of the most promising building greenery systems, few studies of their sound insulation potential have been conducted. In addition, there are different types of green walls; therefore, available data for this purpose are not only sparse but also scattered. To gather knowledge about the contribution of vertical greenery systems to noise reduction, especially a modular-based green wall, two different standardised laboratory tests were conducted. The main results were a weighted sound reduction index (R_w) of 15 dB and a weighted sound absorption coefficient (α) of 0.40. It could be concluded that green walls have significant potential as a sound insulation tool for buildings but that some design adjustments should be performed, such as improving the efficiency of sealing the joints between the modular pieces.

1. Introduction

In the relatively recent past, in society's haste to pursue progress through relentless development, the many advantages that sustainable urbanisation can bring have been ignored. The results of such a short-sighted approach are present for all to see: noise, pollution, congestion and the serious erosion of the quality of city life. Sustainable development requires the consideration of (A) a whole host of interconnected elements, (B) the reduction of energy and water consumption, (C) the minimisation of waste and pollution, (D) the use of environmentally friendly materials, and (E) the availability of efficient public transportation [1].

Urban green space, including the greening of buildings involving both green roofs and green walls, is just one piece of the puzzle. Modern cities provide enormous areas of roof and wall space, in many cases stretching high above the street. Not all of this space is appropriate for growing plants, but much of it is, certainly much more than has been utilised in recent years [1]. Among the benefits that are associated with greenery systems for buildings, such as energy savings, biodiversity support, and storm-water control, there is also noise attenuation [2,3].

Previous studies concerning the sound interception provided by plants refer to the acoustic effect of the belts of trees/vegetation near roads [4]. From these studies, it is known that vegetation can reduce sound levels in three ways. First, sound can be reflected and scattered (diffracted) by plant elements, such as trunks, branches, twigs and leaves. A second mechanism is absorption by vegetation. This effect can be attributed to mechanical vibrations of plant elements caused by sound waves, leading to dissipation by converting sound energy to heat. There is also a contribution to attenuation by thermo-viscous boundary layer effects at vegetation surfaces. As a third mechanism, one might also mention that sound levels can be reduced by the destructive interference of sound waves. The presence of soil can lead to destructive interference between the direct contribution from the source to the receiver and a ground-reflected contribution. This effect is often referred to as the acoustical ground effect or ground dip. The presence of vegetation leads to an acoustically very soft (porous) soil, mainly due to the presence of a litter layer and plant rooting. This

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result is a more pronounced ground effect and produces a shift towards lower frequencies compared to sound propagation over grassland. As a result, this ground dip is more efficient in limiting the typical engine noise frequencies (approximately 0.100 kHz) of road traffic [4].

Generally, it can be considered that the sound insulation effect of vegetation in urban environments is small, with the reductions ranging from 5 to 10 dB. The factors that affect the function of vegetation in sound insulation are multiple, such as the species, the screen dimensions, and the shape and location with respect to the source of the noise. The vegetation itself can reduce noise levels by up to 8 dB and occasionally more [5].

Regarding the sound insulation effects of vegetation when incorporated in buildings, previous studies usually mostly consider the contribution of green roofs to acoustic insulation, while references to green walls are more scarce. In addition to the fact that few studies address the noise reduction that is provided by vertical greenery systems for buildings, we must keep in mind that these constructive systems are very different and, therefore, that their acoustic behaviour will be very different. According to the previously established classifications, the vertical greenery of buildings can be addressed by means of two different construction systems, green walls or green façades [6]. Regarding green walls, also called living walls, basically two main types can be differentiated. The first type uses geotextile felts to support plants without a substrate (Fig. 1), while in the second typology, the substrate and the plants are placed in modules (boxes), either plastic or metal, sometimes pre-cultivated, that are fixed to a vertical support structure or directly to the building façade wall (Fig. 2) [6].

This study focuses on the second type, i.e., module-based green wall. Despite the design differences between companies, module-based green walls are the most widespread system, whereas geotextile-based systems, due to their artistic orientation, have a more limited use.

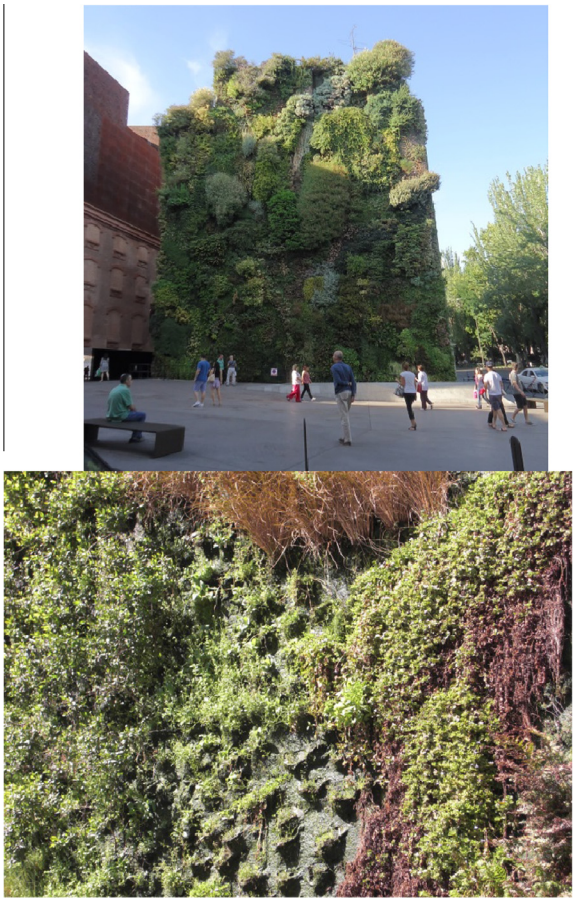

Fig. 1. Geotextile-based green wall.

In reference to the urban noise attenuation by vegetation, Dunnet and Kingsbury stated that the hard surfaces of urban areas tend to reflect sound rather than absorb it. The author highlights that green roofs can absorb sound, with both the substrate and plants contributing. The substrate tends to block lower sound frequencies, whereas plants block higher frequencies [3]. However, in the case of module-based green walls, the substrate is not exposed directly but rather is inserted into a lightweight structure (module or box) that is usually made of plastic or metal; consequently, the acoustic behaviour could change considerably from that offered by green roofs.

From the few studies investigating the acoustic insulation capacity of green walls, it can be deduced that these systems positively contribute to improving the building/city acoustics. However, these experiments are very different, and the results are so diverse that it is difficult to determine the real contribution of green walls, i.e., the acoustic insulation level that is provided by green walls.

Wong et al. conducted a study to evaluate the acoustic impacts of different vertical greenery systems on the insertion loss of building walls [7]. From the results of this study, it can be concluded that the insertion loss shows a stronger attenuation to middle frequencies due to the absorbing effect of the substrate, while a smaller attenuation is observed at high frequencies due to scattering from greenery. Although not every studied vertical greenery system exhibits a good noise reduction, low to middle frequency range reductions of approximately 5–10 dB were measured. For the high frequencies, the insertion loss reductions ranged from 2 to 3.9 dB, except for one, which reached the maximum value of 8.8 dB. However, a second objective of the Wong et al. study was the sound absorption coefficient determination of a green wall in a reverberation chamber. From this experiment, it can be concluded that the sound absorption coefficient of the studied greenery system has higher values than those of other building materials and furnishings. Moreover, it can be confirmed that the absorption coefficient increases with increasing frequencies and with larger greenery coverage.

Positive results were found by Fernández-Bregón et al. when studying the effects of vertical greenery on the thermal and sound mitigation for indoor walls [8]. For the effect on sound mitigation, the average decrease in dB was between 2% and 3%, using frequency weightings that were equivalent to the sound frequencies that the human ear perceives, without and with excluding extreme frequencies, respectively.

Van Renterghem et al. carried out a numerical study of road traffic noise, which is the most important and widespread environmental noise source in the urban environment and the potential of building envelope greening to achieve quietness [9]. Three types of theoretical measures were considered, green roofs, green walls and vegetated low-height noise barriers positioned near roof hedges. The conclusions of this study stated that the effects of wall vegetation strongly depend on the assumptions of the material parameters in the reference case. While acoustically softer bricks were assumed, i.e., the use of a reflection coefficient of 0.82, the effectiveness of green walls becomes rather modest: the maximum effect remains below 2 dB. Additionally, some inconsistencies at very low frequencies appear because the measured absorption coefficients of the wall vegetation could become smaller than those of bricks. However, calculations using a reflection coefficient of 0.95 could be considered as yielding the maximum possible effects: an insertion loss of 4.4 dB in the case of fully vegetative-source canyon façades. This study indicates that the substrates that are usually used for green walls have a high porosity and low