Noise control by Hedges and Woods

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Introduction

Hedges and woods perform in our environment important duties: they filter the air, produce oxygen, act as fencings, blinds and windbreaks, provide habitat for birds and insects and improve the microclimate of urban areas. However, for noise control in urban planning, they are rarely utilised. The main reason for this is that the damping of the plants is regarded very low in the relevant planning directives, so that a noticeable sound reduction can only be achieved by large-area green space. For example, the damping constant for 1000 Hz in ISO 9613-2 [1] is 0.06 dB/m, giving a damping of 3 dB for a green space of 50 m width. In the literature, values of damping of natural vegetation more then ten times higher have been reported [2-4]. Until now, very little knowledge on the acoustic properties of hedge plants is available. In a research project the basic acoustical properties of hedges and woods are investigated. The research study will comprise measurements and computer simulation. The focus is to gain information on the damping and absorption coefficients, to characterise hedges and woods and to provide reliable data on the acoustic properties of hedges for urban and landscape planning. First results of the investigation are reported.

Preliminary Measurements

For first measurements on plants, a standing wave tube was selected. It had a quadratic cross-section of 250 mm x 250 mm and a length of 7.5 m. The tube size was chosen to enable measurements on structures similar to hedges. Unfortunately, the size restricted the frequency range to 40 to 1000 Hz. As source two loudspeakers were used, which produced a plane wave inside the tube. A MLS-Signal (Maximum Length Sequence) was utilised to enhance the signal to noise ratio. The loudspeakers were covered by absorption material, to reduce reflections of waves at this end of the tube. The other end was reflective for measurements of the sound absorption coefficient, or equipped with absorbing wedges to measure the insertion loss of probes.

Figure 1: Standing wave tube used in first measurements.

For first measurements the following hedge plants were selected: Fly Honeysuckle (Rote Heckenkirsche / *Lonicera xylosteum*) and Common Dogwood (Blutroter Hartriegel / *Cornus sanguinea*). These plants were easily available and have leaf sizes and structure regarded as usual for common hedges. Additionally an artificial plant was used for comparison: Replica of leafs and branches of the Bengal Fig (Bengalischer Feigenzweig / *Ficus benghalensis*). Leaf size and density as well as appearance of the branches were similar to the natural probe material.

First tests were performed on sheets consisting of leafs. To do so, leafs were glued together to the size of 250 mm x 250 mm with a minimum overlap. The probes were attached to a small wooden frame, see figure 2 a).

a) b)

Figure 2: Probes for standing wave tube. a) sheet made by leafs glued together, b) probe of plant material in a lattice box.

For further measurements, a lattice box was constructed, where probe material was filled in, Figure 2 b). Measurements on the lattice box are reported following to the measurements on the sheets. Tests of the empty Frame and lattice box showed that they didn’t affect the measuring results.

Sheets of natural and artificial leafs

First the insertion losses of sheets made of the different leaf material were measured. For comparison also a sheet of paper was included. Results are given in Figure 3.

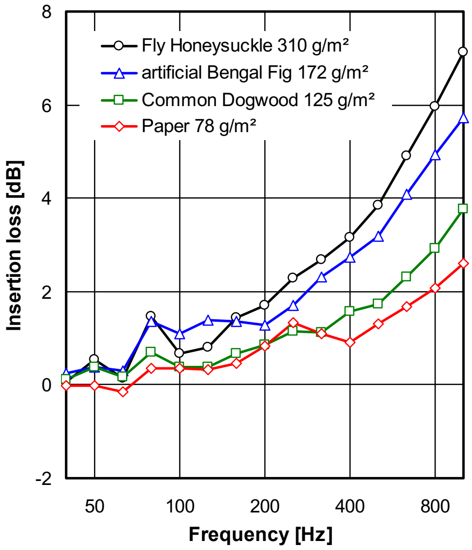

Figure 3: Insertion loss of sheets made of natural and artificial leafs and of a sheet of paper.

Results show for all probes a limp mass behaviour, with an increase of the insertion loss with frequency and with mass per unit area. At 100 Hz values of the insertion loss lie between 0 and 1 dB, at 1000 Hz the sheet of paper reaches 2.6 dB and the sheet of Fly Honeysuckle 7.1 dB.

The sound absorption of all sheets, when placed in front of a reflective surface, is shown in figure 4.

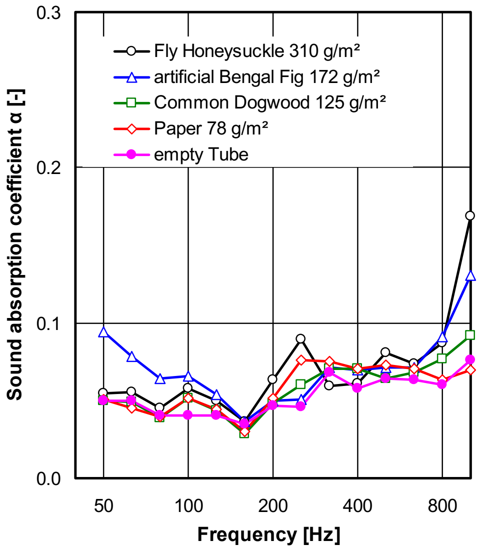

Figure 4: Sound absorption coefficient of sheets made of natural and artificial leafs and of a sheet of paper.

The results of the sound absorption coefficient show, that for all probes the sound absorption is close to the absorption of the empty tube. As expected, the surface of the leafs provide low sound absorption due to their dense, reflective surface.

Volume of plant material, similar to hedge structure

The second kind of probes preliminarily tested were plant material of leafs and branches in a lattice box, figure 2 b). The lattice box was acoustically transparent and had a size of 250 mm x 250 mm x 170 mm. Again the same plants were used. For each plant, two filling densities were tested: a lower filling density similar to real hedges and the double density, to investigate the influence of the density on the acoustical properties. Results for the insertion loss are shown in figure 5.

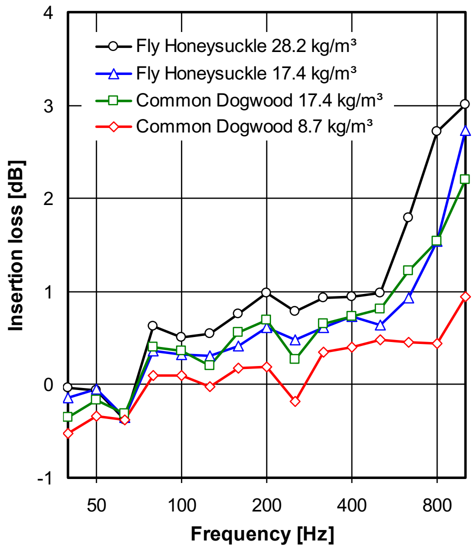

Figure 5: Insertion loss of plant material in a lattice box.

Again, with higher density the insertion loss increases. At low frequencies below 80 Hz the measurements show erroneous data below 0 dB. From 80 Hz to 500 Hz the insertion loss reaches values between 0 and 1 dB. Above, with increasing density a strong increase of insertion loss occurs, giving values up to 3 dB at 1000 Hz for Fly Honeysuckle with 28.2 kg/m^3 density. The insertion loss of both plants with similar filling density is quite similar, suggesting that the filling density is more important then the plant species and the difference in leaf weight of the plants. To describe the insertion loss by a single value descriptor, DL_R according to EN 1793-2 [5] was used, in the restricted frequency range from 100 to 1000 Hz. For Common Dogwood with 8.7 and 17.4 kg/m^3, $DL_{R,100\text{-}1000}$ was calculated to 0.5 and 1.3 dB, Fly Honeysuckle with 17.4 and 28.2 kg/m^3 gave $DL_{R,100\text{-}1000}$ of 1.3 and 1.8 dB, respectively.

For the same probes in the lattice box, the sound absorption coefficient was measured by placing the probes in front of a sound reflecting surface. Results are shown in figure 6. For all probes the sound absorption coefficient stays low at about 0.1 at low frequencies up to 100 Hz. Above 100 Hz values start to rise, especially for Fly Honeysuckle with 28.2 kg/m^3 density, which reaches values of 0.47 at 400 Hz. At 630 Hz a minimum of absorption arises for the heavy Fly Honeysuckle probe, above which it rises steeply to values of 0.72 at 1000 Hz. All other probes gave lower absorption with a similar pattern and a minimum of absorption at 800 Hz third octave band.

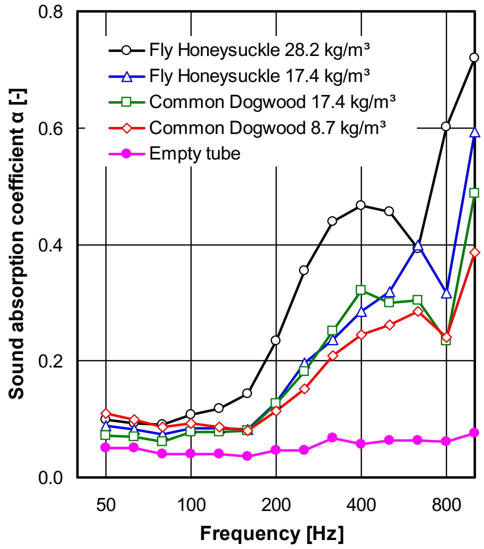

Figure 6: Sound absorption coefficient of plant material in a lattice box.

Probe thickness

To investigate the influence of the probe thickness on the insertion loss, three probes were tested with nearly equal filling density. As probe material, leafs and branches of the artificial Bengal Fig was used. The artificial plant is independent of wilting and provides good reproducibility. Results for probe thickness of 100, 200 and 300 mm are shown in figure 7.

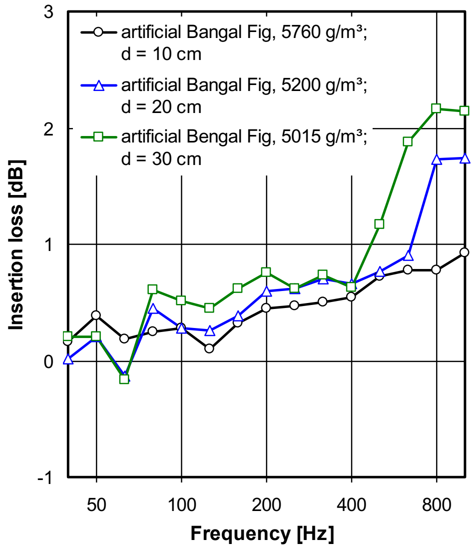

Figure 7: Insertion loss of artificial Bengal Fig in a lattice box with 100, 200 and 300 mm probe thickness.

At frequencies below 500 Hz, the insertion loss gives values below 1 dB, with a slight increase with increasing frequency. At higher frequencies, the insertion loss rises steeply. The steep slope shifts to lower frequencies when probe thickness increases. Therefore, $DL_{R,100\text{-}1000}$ reaches 0.7, 1.2 and 1.3 dB with increasing probe thickness, respectively. The (frequency dependent) extrapolation of the insertion loss to a probe thickness of 1 m leads to values for $DL_{R,100\text{-}1000}$ of 6.6, 5.1 and 4.6 dB/m for probe a thickness of 100, 200 and 300 mm, respectively. This result shows, that the simple model of ISO 9613-2:

$$\Delta L = \alpha\, S \qquad [\text{dB}] \qquad (1)$$

with ΔL the insertion loss, α the damping in dB/m and S the sound path length inside the vegetation in m, does not apply to structures like hedges. Therefore, a more sophisticated model should be developed to describe the insertion loss of such structures. Further, the described preliminary measurements will be continued by measurements on real hedges in the laboratory and in the free field.

Conclusions

The results show that the insertion loss of leafs can be described by limp mass behaviour. Therefore, the most relevant property of leafs regarding the insertion loss is the mass per unit area of the leaf.

The artificial plant Bengal Fig gives similar insertion loss and sound absorption as natural plants and was used to study the influence of probe thickness, as it does not wilt and therefore provides better reproducibility as natural plants.

For plant material (leafs and branches) the insertion loss depends on the filling density of the probes. The measurements on probes of two different plant species showed similar results, if the filling density was equal. For the sound absorption coefficient results were again dependent on the filling density. As before, probes of different species gave similar absorption coefficients at equal filling density.

Further tests have to reveal, if the filling densities tested are representative for real hedges, and if the results can be reproduced on real hedged. Therefore measurements on real size hedges in the laboratory and in the free field are next steps in this project.

References

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