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Scale model study of road traffic noise reduction by planting schemes

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Summary
It has been suggested that (structured) planting schemes for trees and profiled ground can have a significant influence on noise propagation. To reduce the sound pressure level in certain spectral bands, the distance between the trees, the diameter of the trunk base, the height of the tree, etc are significant parameters. They also determine which tree species are applicable. Because 3D numerical models are often computationally too costly to study this effect, and since 2D simulation models do not incorporate a ground surface, a scale model experiment has been set up. Rows of trees and ground profiles are modeled. More specific, several ordered planting schemes with various tree trunk diameters are evaluated in combination with rigid ground profiles. Focus is on vegetation belts with a limited depth. The distance between trees and their position within the planting scheme as well as the trunk diameters are based on realistic parameters of bunch management systems. Because of the multiplicity of tree species and the support of bunch management, many context-tied solutions can be obtained to reduce traffic noise as long as certain conditions of the trees are fulfilled. The results show that specific planting schemes should be considered when planning to reduce specific parts of the traffic noise spectrum by vegetation belts along urban roads.

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1. Introduction

Over time, infrastructural networks got strongly embedded in the urban tissue of European cities, creating public spaces with an unintelligible urban environment. Realizing that the quality of life decreases due to those incoherent urban areas, more and more cities start to renovate their public spaces. In urban master plans, architects often propose green parks as a buffer zone between infrastructural networks and quiet urban sites. In these parks the sound pressure level can be effectively reduced by installing industrial noise screens, which unfortunately degrade the natural character of the park and disturb the view of the city dweller. By introducing trees planted according to ordered planting schemes, specific spectral components of context-tied dominating sound events could potentially be kept out of these quiet park areas [1]. Also the quality of the air polluted by the exhaust of the traffic can be improved by the greenery.

The request of architects and landscape designers for aesthetic noise abatement alternatives and the lack of detailed information on optimal use of vegetation for noise control, some basic design parameters for planting schemes of trees have been investigated. Because 3D numerical models are often computationally too costly to study this effect, and since 2D simulation models do not incorporate a ground surface, a scale model experiment has been set up.

In this 1/20 scale model experiment several ordered planting schemes with of trees are modeled. Additionally, ground profiles have been evaluated and combined with tree trunks. The focus of this experiment is on vegetation belts with a limited depth and as a result applicable in many urban configurations.
All the parameters of the planting schemes are based on realistic parameters of bunch management systems [2].

2. Measurement setup

To evaluate the influence of the planting schemes of trees, a scale model has been set up. The scale model is placed on a rigid ground-plate inside an anechoic chamber. Fig. 1 shows the setup and dimensions of the scale model compared to a real life situation. To simulate a point source on a specific height of the ground a tweeter is placed underneath the ground-plate as shown in Fig.2. The sound source is used to reproduce an exponential sweep with frequencies between 500 Hz and 23 kHz in the scale model. During the measurement cycle, the sweep is repeatedly recorded by a 1/2” microphone. The microphone is mounted on a mechanical arm, which automatically moves along an array of measurement positions. Due to reflections on the tree trunks [3], no reference microphone could be used to evaluate the reproducibility of the sound source signal. To fully exclude changes in source emission over time, sound propagation over a rigid plane has been recorded after each measurement and the insertion loss (IL) of the trees compared to this reference has been calculated.

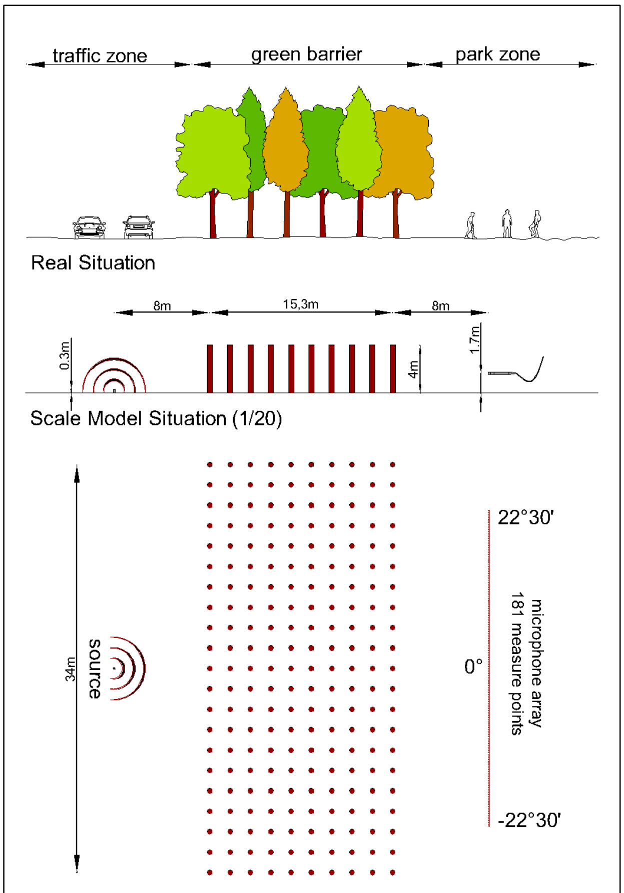

Figure 1. Urban configuration and scale model approach

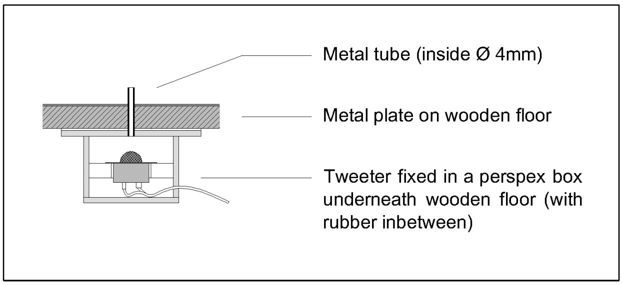

Figure 2. Point source at 0.3 m height

3. Results and discussion

Focus of the experiment is on the low frequency engine noise peaks, near 100 Hz. The insertion loss of different tree trunk organizations and ground covering has been evaluated. As shown in Fig.1, measurements have been carried out on 181 positions, all equally spaced. When using reciprocity of source and receiver position, integrating the results over such a line is representative for a situation with a fixed receiver and a moving point source along the green barrier (pass-by of a car). A more detailed analysis is possible by representing the data in 1/6th octave bands.

3.1. Planting Schemes of trees

In the first part of this paper, we evaluate whether ordered trees arrangements are advantageous for noise abatement. By planting trees in a specific lattice, ‘sonic crystal’ effects might be obtained for low frequencies and also shielding effects for the higher frequencies are expected. Fig.3 shows an overview of tree trunk configurations that have been examined to investigate the influence of planting parameters of trees. For all the configurations, except for the trunk diameter and spacing, the trunk diameter is 0.44m and the spacing between the trunks is 1.7m.

3.1.1. First row position

As show in Fig.3a the influence of the first row position for 4 rows of trees with a constant spacing and trunk diameter has been analyzed. The graphs in Fig.4a show that the magnitude of the low-frequency IL peak corresponding to the basic lattice spacing is large and the high-frequency shielding effect is distinct if the first row is closer to the source. If the last row of trees is closer to the receiver position, the ‘bandgap’ effect is also slightly bigger then for the middle configuration. For the middle and the back position, the shielding effect is less pronounced.

3.1.2. Spacing between trunks

For a simple cubic lattice the spacing between the trees is varied as shown in Fig.3b. The results presented in Fig.4b show that the low-frequency IL peak depends on the lattice spacing and this effect decreases by increasing the distance. For a tree spacing of 3.4m no ‘bandgap’ effect is observed anymore. Also the shielding effect decreases with increasing space between the trees.

3.1.3. Patterns

Three patterns (SC, FCC, HEX) and one random configuration have been set up to observe the effect of difference lattice types (Fig. 3c). For these patterns the minimum distance between the trees is constant and for the random configuration the quantity of the tree trunks is the same as for the SC lattice. As expected the ‘bandgap’ effect can only be observed when the tree configuration is according to an ordered scheme. For the different patterns, the first pronounced IL peak ($\simeq\lambda/2$) will shift to another frequency in relation to Bragg’s law for each specific lattice type. For the HEX pattern a 2nd IL peak is obvious present.

Compared to the shielding effect of a SC lattice, the FCC and HEX lattice performs better because the rows are alternating shifted. Also for the random configuration the shielding for the higher frequencies is high as well.

3.1.4. Number of rows

Fig.3d shows the test setup to examine the influence of the number of tree rows. For 2 rows this effect is more or less negligible. By increasing the number of rows to 4 or 6 rows, small effects can be seen for the pronounced IL peak at the lower frequencies and also for the high-frequency shielding. It can be said that from 8 rows the band gap and shielding effect is significant. By adding more tree rows the effects will stagnate.

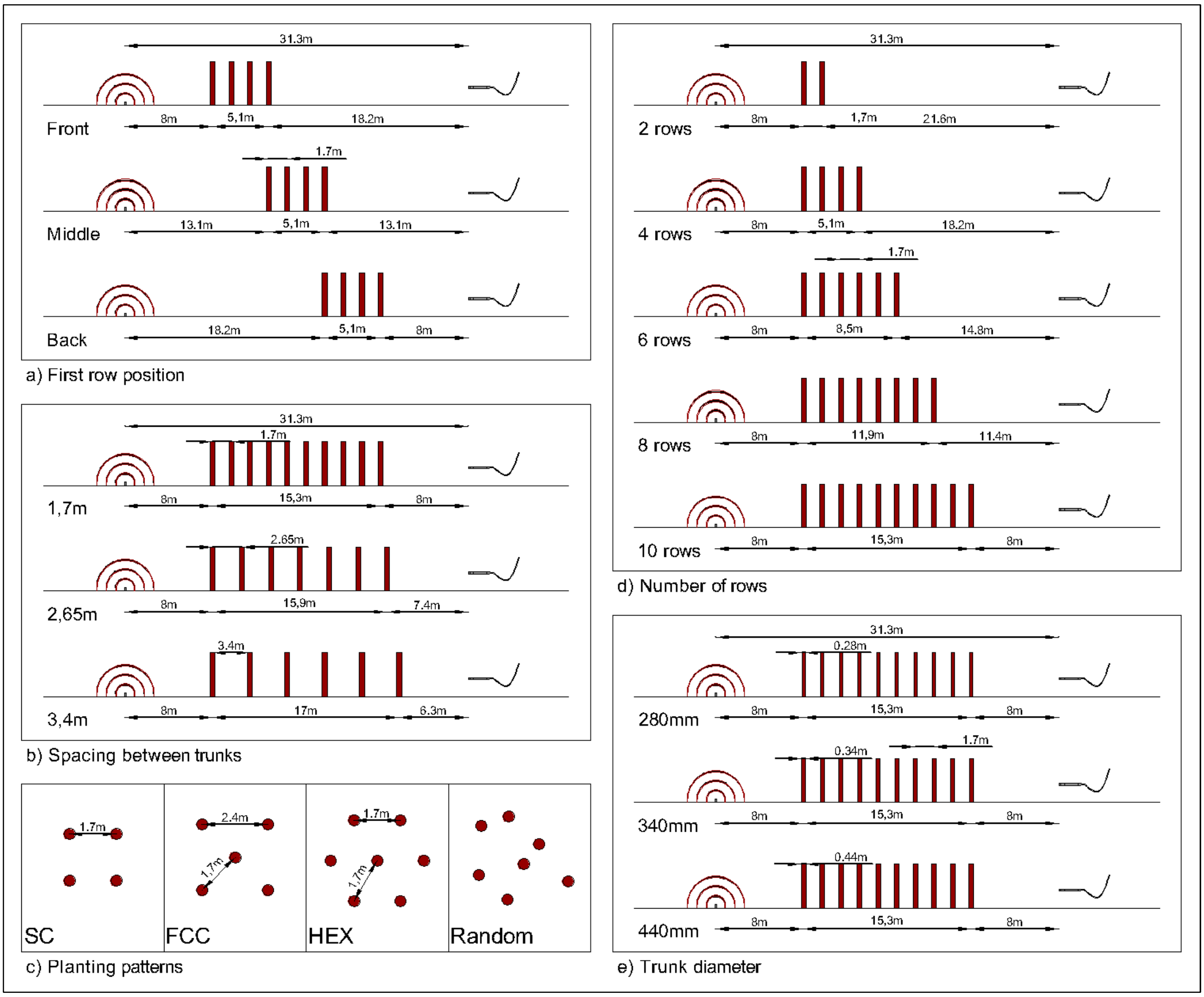

Figure 3. Tested configurations of planting schemes

3.1.5. Trunk diameter

Several trunk diameters have been tested (Fig.3e). The results in Fig.4e show that a sufficient trunk diameter is important to obtain a confident low-frequency IL peak. Also for the shielding effect the size of the tree trunk matters, but less pronounced.

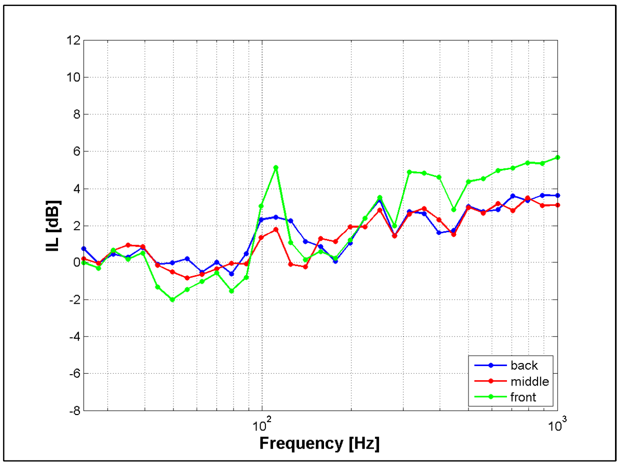

Figure 4a. First row position

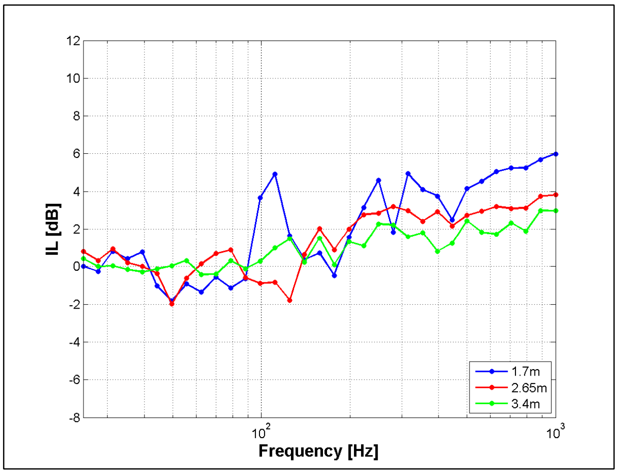

Figure 4b. Spacing between trunks

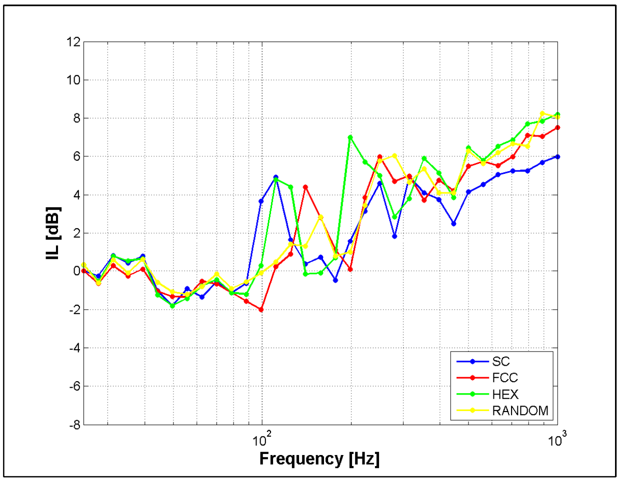

Figure 4c. Patterns

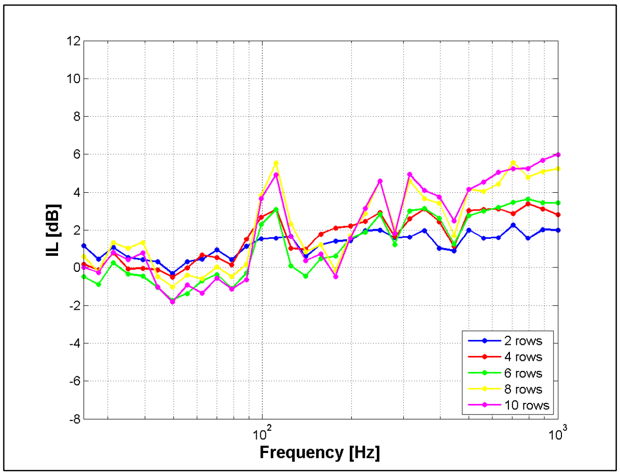

Figure 4d. Number of rows

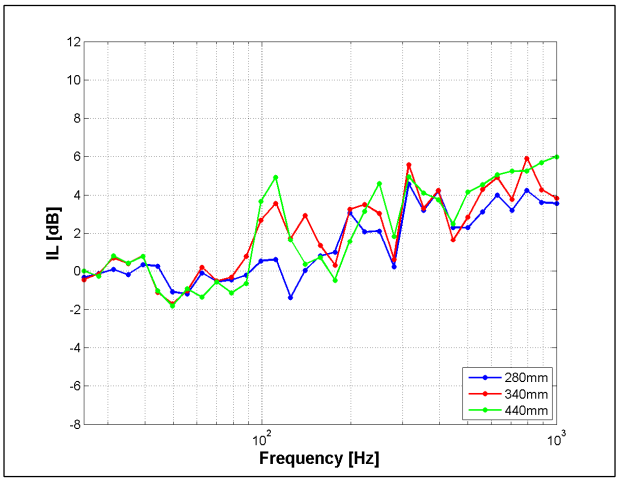

Figure 4e. Trunk diameter

3.2. Profiled ground

The previous evaluated configurations were all performed on a rigid flat plane. To investigate the influence of a rigid profiled ground surface the set ups shown in Fig.5 have been tested.

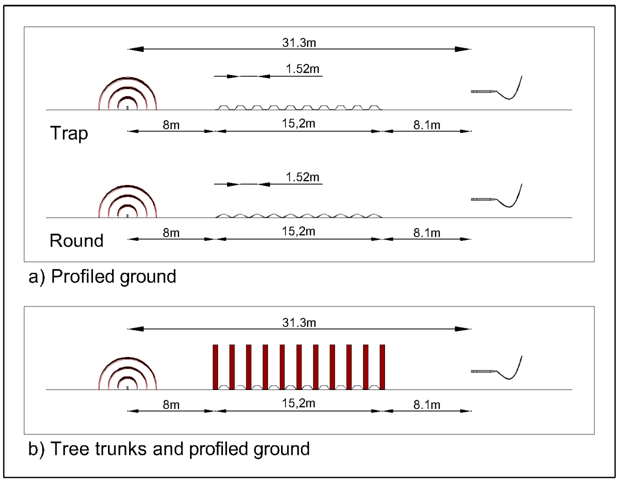

Figure 5. Tested configurations of profiled ground

3.2.1. Ground profiles

A rigid trapezoid and round wavy profile have been examined as figured in Fig.5a. The distance between two consecutive waves is 1.52m and the height of the profile is 0.36m. The dimensions of the profiles are identical in both cases and so are the results. As soon as the geometrical period of the profile exceeds half the sound wavelength, a significant increase in the IL is obtained (Fig.6a). For the higher frequencies the effect of the profiles reduces. A downward peak manifests for the 50 Hz 1/6th octave..

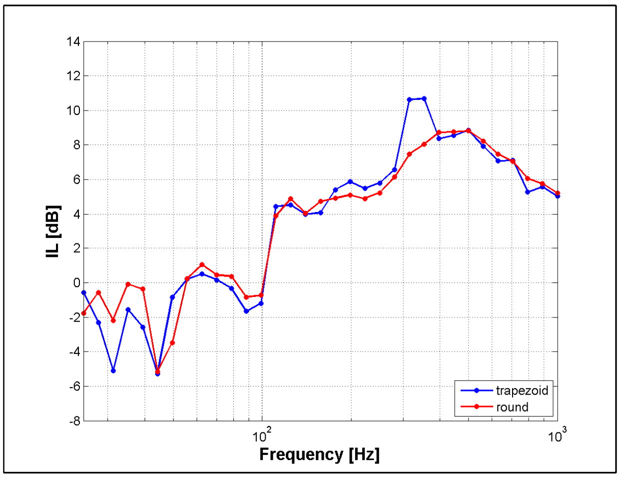

Figure 6a. Ground profiles

3.2.2. Tree trunks and profiled ground

As shown in Fig.5b the trapezoid ground profile (wave period = 1.52m) has been combined with a simple cubic (SC) lattice of the tree trunks (diameter = 0.44m, spacing between trunks = 1.52m). The graph in Fig.6b shows that the pronounced IL peak increases due to the combination of tree trunks and profiled ground, as the target frequency is the same. Also the shielding effect is reinforced by the coupling. Also here the downward peak manifests for the 50 Hz 1/6-octave band.

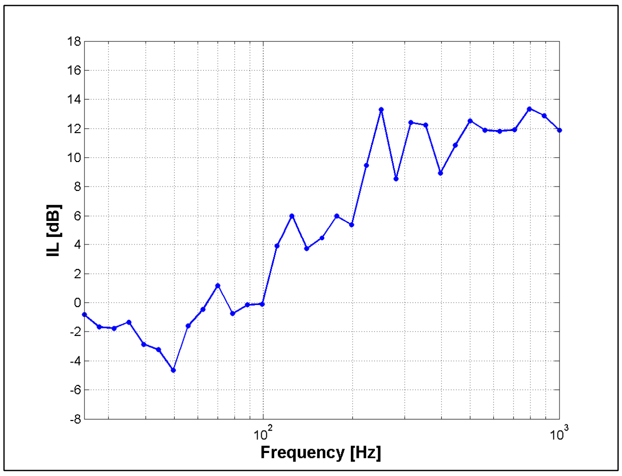

Figure 6b. Tree trunks and profiled ground

4. Conclusion

In this paper, a few basic design parameters for ordered planting schemes of trees have been analyzed. The results have shown that the concept of ‘sonic crystals’ is applicable on planting schemes of trees, and although its effect on overall A-weighted traffic noise might be limited, unwanted low frequencies could be removed more efficiently using these planting schemes.

It can be observed that the distance between the source and the first row of the planting scheme has an important influence on the shielding. The number of rows in the lattice plays an important role in the shielding effect of the green barrier. By increasing the spacing between the consecutive trees the ‘bandgap’ effect and the shielding effect decreases. For the different lattice types and the random configuration the shielding effect is more or less the same, but the ‘bandgap’ effect is only introduced when the planting scheme of the trees is according to a specific lattice (ordered). Also the trunk diameter of the tree must be sufficiently large enough to have a pronounced IL peak corresponding to the basic lattice spacing and to obtain the effect of shielding for higher frequencies.

Furthermore, the profiling of the ground has been investigated. As soon as the geometrical period of the profile exceeds half the sound wavelength, the IL increases significant for both trapezoid and round profiles. Eventually, the combination of tree trunks and a profiled ground have been compared. Adding a rigid profiled ground to the ordered planting scheme of the trees (SC) increases both ‘bandgap’ and shielding effect significantly.

Acknowledgement

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