SCALE-MODEL INVESTIGATION OF THE EFFECTS OF SURFACE ABSORPTION AND NEARBY FOLIAGE ON NOISE-BARRIER PERFORMANCE

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ABSTRACT

Two factors that may affect the acoustical performance of highway noise barriers – surface absorption and nearby vegetation – were investigated using a 1:31.5-scale model highway. Model materials were chosen by performing excess-attenuation measurements and a best fit to find the effective flow resistivity. Surface absorption was tested on single and parallel noise barriers of varying heights, allowing for a comparison between adding absorption and increasing the height. Foliage tests were performed on single and parallel barriers with various configurations of model trees. Barrier absorption prevented the amplification of sound between parallel barriers; in this case, adding absorption to the full source side of the barriers was equivalent to increasing the height of the barriers by 0.33 m. The foliage test results showed that both scattering and absorption occurred, increasing and decreasing barrier performance by up to 4 dB.

SOMMAIRE

Deux facteurs qui peuvent influencer la performance acoustique des écrans routiers – l'absorption des surfaces et de la végétation adjacente – ont été étudiés à l'aide de la maquette d'une configuration routière à l'échelle réduite de 1:31.5. Les matériaux pour la maquette ont été choisis par l'intermédiare de tests d'atténuation excédentaire qui permettaient de determiner la meilleure approximation de la résistivité à l'écoulement à partir des mesures prises. L'effet de l'absorption surfacique a été testé sur des écrans simples et paralèlles de différentes hauteurs, ce qui a permis une comparaison entre les effets de l'absorption et d'un écran plus haut. D'autres tests ont été faits avec des écrans simples et paralèlles en présence de diverses configurations de végétation. L'absorption surfaçique a empêché l'amplification du son entre les écrans paralèlles; le rajout de l'absorption à la surface entière de l'écran côté source a été équivalent à une augmentation de la hauteur de l'écran de 0,33 m. Quant à la végétation, elle a causé et de la diffusion et de l'absorption, tout en augmentant et diminuant la performance jusqu'à 4 dB.

1 INTRODUCTION

Roadside noise barriers are a commonly used method of traffic-noise control. Two factors which may affect the performance of roadside noise barriers were under consideration here. The first was using absorptive surfaces to reduce unwanted amplification between parallel reflective barriers. The second was the effect of foliage near a barrier; noise behind the wall may decrease, due to back-scattering and absorption of the foliage, or increase, because sound which would normally pass over the wall is scattered into the shadow zone. Acoustical scale-modelling was used to investigate these, as it allows ideal conditions to be created. Full details of the study are found in [1].

Some work has already been done to study absorptive noise barriers using scale-modelling. Osman [2] developed a 1:16 scale-model facility, used to study different shapes of noise barriers, both reflective and absorptive [3]. Menge [4] studied the effects of using sloped barriers instead of absorption to reduce amplification between parallel barriers, using a 1:30-scale model. Trucks were the dominant source of noise in the specific case considered; therefore the 250-, 500- and 1000-Hz octave bands were studied. He used 16-mm medium-density overlay plywood with smooth, dense paper glued to both sides to model concrete, asphalt, brick and steel, as well as the reflective, sloped barriers. He used fiberglass for the absorptive barriers. He used an electric spark discharge as an impulsive sound source and a ¼-inch microphone as the receiver. Hothersall *et al.* [5] used a 1:20-scale model to test reflective and absorptive railway noise barriers. They used a polished-aluminum surface to simulate rigid ground and specially manufactured, 8-mm-thick porous plastic plates to simulate grass. The barriers were modelled using plastic or steel and were made absorptive by adding a layer of felt.

Busch [6] created a scale model to investigate noise walls, earth berms, and a combination of the two. He used an air-jet noise source and performed excess-attenuation experiments to determine both the optimal scale factor and the materials to be used. He chose a scale-factor of 31.5 and created the model in an anechoic chamber to represent outdoor conditions. He tested the anechoic chamber thoroughly and determined that it was an appropriate testing environment for the scale-model. He used varnished particle-board to model roadways, dense polystyrene to simulate noise walls, and expanded polystyrene to model soft ground and earth berms. He used felt and expanded polystyrene to make the earth berms softer and harder, respectively.

When discussing the cost effectiveness of absorptive noise barriers, as opposed to reflective barriers, it is convenient to know the equivalent barrier height increase required to obtain the same IL improvement as an absorptive barrier. This was a specific objective of this absorption work.

While much work has been done on studying sound propagation through foliage, there have been only a few studies on the effects of the performance of barriers located near foliage. Cook and Van Haverbeke [7] studied the combination of barriers and trees as a method of noise control. They compared the total, A-weighted sound levels behind different configurations, including bare walls, trees and walls with trees, with no walls or foliage. They found that trees gave approximately 4-5 dBA of attenuation, while a bare wall gave 10-11 dBA and trees with a wall gave 13-14 dBA. Renterghem *et al.* [8] studied the effect of using tree foliage as a wind screen to prevent the refraction of sound around a barrier in a downwind direction. They created a 1:20 scale model in a wind tunnel and used wind screens to model the scale-model trees. They first confirmed the decrease in IL when wind was present, finding IL decreases of up to 8 dB at a distance of 10 times the barrier height away from the barrier. Once the wind screens were inserted, in the absence of wind they found that the change in IL was very small and sometimes negative. They attributed this to the scattering by the wind screen. At greater distances, when wind was present, the windscreen always increased the IL, by up to 4 dB. When the receiver was closer than five times the height of the barrier, no effect was greater than 1 dB. They did not present any frequency-dependent data in this study.

Renterghem *et al.* [9] also performed field tests, in which measurements behind a noise barrier with and without trees were compared. They did a frequency-dependent study on noise levels behind a barrier with and without a single row of 8 m tall trees behind it in the absence of wind. They found that, at low frequencies, noise levels in the no-trees case were higher; above 1000 Hz they found that noise levels in the treed case were higher, with all effects under 5 dB.

In previous studies, the effect of wind was shown to be an important factor affecting barrier performance, but wind was not studied here. In previous studies on the effects of foliage on noise barriers, little frequency-dependent data was reported. However, in studies focusing on sound propagation, the attenuation provided appeared to depend heavily on frequency. Therefore, performing a full frequency-dependent study of the effects of foliage was an objective here. The 1:31.5-scale model originally developed by Busch [6] was redeveloped here and tested in the same anechoic chamber that he used, to examine the two factors under investigation: absorptive barriers and foliage near barriers.

2 THEORY

When creating an accurate scale model, there are many factors that must be taken into consideration. For a scale factor n, all dimensions and distances are scaled by $1/n$. The

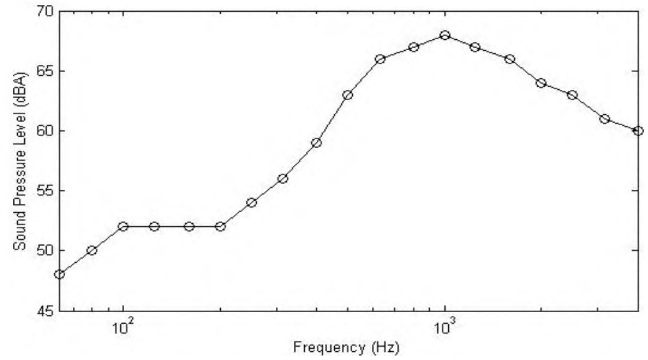


Figure 1. Typical A-weighted traffic-noise spectrum used to determine total A-weighted IL's [6].

speed of sound remains the same in the scale model; to ensure that the relation between distance and the acoustical wavelength remain constant, the wavelength must become λ/n; therefore the frequency f must be scaled up to nf. Issues occur at these higher frequencies, such as air absorption becoming very significant. The directionality of the microphones is also a problem at high frequencies, as one wants the microphone to be as omni-directional as possible, and therefore the smallest microphones available must be used. Furthermore, because the wavelengths of the frequencies of interest are small, the protection grid on the microphone must be accounted for, as it is no longer a negligible size at these frequencies and may affect the frequency response. It is assumed here that effects such as diffraction and interference are consistent under scaling.

Selecting appropriate scale-model materials is crucial to the accuracy of a scale model. The method of selection here was used by Hutchins *et al.* [10] and Busch [11]. Materials to be used in an acoustical scale model must be found which have the same acoustical impedances at scaled-up test frequencies as real-world materials do at full-scale frequencies. The impedance of a fibrous material can be predicted approximately by the simple Delany-Bazley empirical model [12]:

$$Z = 1 + 9.08\left({f}/{\sigma}\right)^{-0.75} + i11.9\left({f}/{\sigma}\right)^{-0.73}$$

where σ is the flow resistivity in c.g.s. Rayls/cm. Since the frequency is scaled by the scale factor n in the model measurements, the flow resistivity must also be scaled by n to keep Z constant. It is the flow resistivity divided by the scale factor n, called the effective flow resistivity, which is compared to real-world values.

The results in this work that are presented as A-weighted insertion losses (IL's) were calculated using the A-weighted traffic-noise spectrum in Figure 1 – determined from many traffic-noise measurements – as a reference. The power output of the sound source was subtracted from the measured noise levels; then the A-weighted traffic spectrum was added, before summing the levels over all frequencies to get a total, A-weighted value. The A-weighted IL was the difference between the values with and without the barrier.

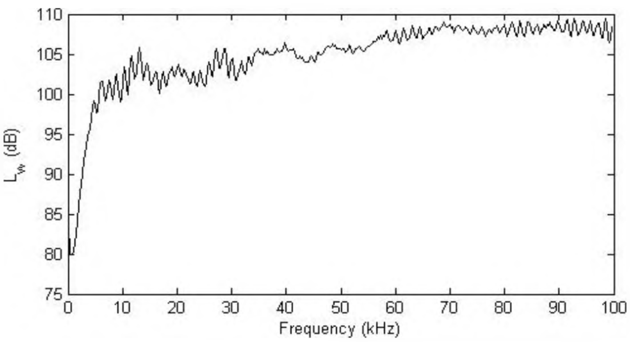


Figure 2. The output sound-power level of the air-jet source.

3 EXPERIMENTAL SET UP

The scale-model measurements were performed in an anechoic chamber with dimensions 4.1 m x 4.7 m x 2.6 m. A 1/4" Bruel & Kjaer type 4135 free-field microphone, the smallest available, was used as the receiver, with a type 2669 pre-amplifier and a 1/2" to 1/4" adaptor. A Nexus Conditioning Amplifier was used mainly for cable-adaptation, and was set as a high-pass filter with a cut-off frequency of 20 Hz. The output sensitivity of the amplifier was set to 31.6 mV/Pa. A Stan-ford Research Systems SR-770 FFT Network Analyzer was used to average and record the acoustic signal in 400 spectral bins, 250-Hz wide, from 0-250 Hz up to 99,750-100,000 Hz. Each measurement involved 2000 spectral averages. The results were stored on 3.5" floppy disks and analyzed in MATLAB. In order to determine the air absorption, the temperature and humidity were measured with a Psychro-Dyne psychrometer.

3.1 Air-Jet Source

The sound source used here was the air-jet source used and tested by Busch [6], who provided a detailed description and the results of in-depth tests of the source in the anechoic chamber. The air-jet source, designed specifically for scale-model traffic noise, was developed from the description by Novak [13]. An ideal source must have sufficient power output for a broadband spectrum up to 100 kHz, which corresponds to about 3000 Hz at full scale, and be approximately omnidirectional. The output sound-power level spectrum of the air-jet was measured and is shown in Figure 2. The source was made of six co-planar jets, each with a diameter of 0.3 mm, spaced at 60° intervals around a cylinder with a diameter of 6.5 mm. The outer housing and the core piece were both made of brass. The core piece had resonant cavities which amplified the source power at lower frequencies. Figure 3 shows the source in cross-section.

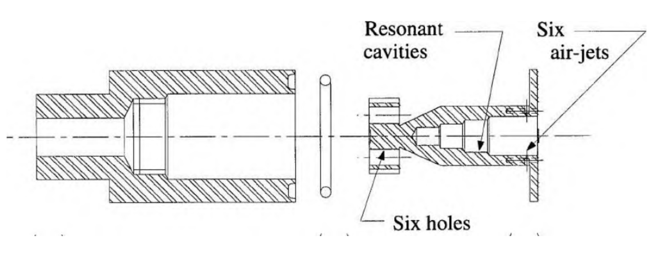


Figure 3. The air-jet noise source in cross-section [13].

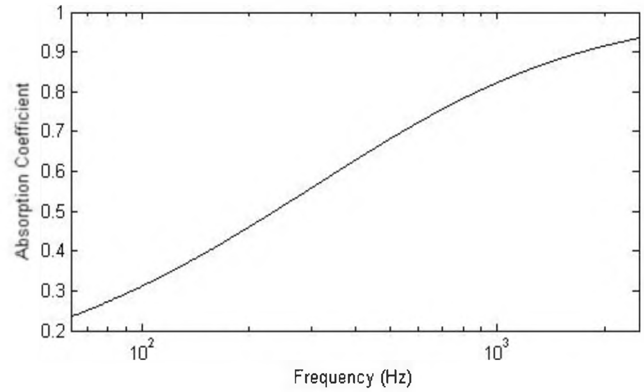


Figure 4. The effective absorption coefficient of the fuzzy blanket.

3.2 Scale-Model Materials

The model-material selection process used here was used by Hutchins *et al.* [10] and Busch [11]. The flow resistivity values were estimated by taking excess-attenuation measurements; scale-model materials were then chosen by comparing these values with real-world material values. Asphalt was modelled by 3/4" painted plywood, the roadside by two layers of linen, a green fabric was used to model grass, 3-mm-thick dense plastic modelled the reflective barriers and a fuzzy blanket was added to the source side of reflective barriers to make them absorb like commercial sound-absorptive barriers [1]. Figure 4 shows the effective absorption coefficient of the absorptive blanket; Table 1 lists the effective flow resistivities of the scale-model materials.

3.3 Scale-Model Trees

Scale-model trees were used to model tree foliage approximately; one of the trees is shown in Figure 5. The model trees were 17.5-cm tall, corresponding to a full-scale height of 5.5 m. To characterize the foliage, scattering and absorption by the trees were measured. The sound source, at a full-scale height of 1 m, was located over grass, modelled by the green fabric, 10 m from a line of trees. Receivers were placed 5 m in front of and 5 m behind the row of trees, at a height of 1 m. The sound pressure level was measured at both receiver positions, with and without the row of trees present. From this, the tree IL was calculated, by subtracting the level with trees from that without trees.

This measurement was repeated at full-scale, on a hedge along the length of a rugby field on the University of

Table 1. Effective flow resistivities (σ_{eff}) of scale-model materials.

Material	σ_{eff} (c.g.s. Rayls/cm)
Fuzzy blanket	33
Green fabric	253
Two layers of linen	430
Dense plastic	20,000

Plywood	35,500

Figure 5. Scale-model tree.

British Columbia campus [1]. The insertion losses from both the scale-model measurements and the full-scale measurements are presented in Figure 6.

There were some similarities and some large differences between the scale model and the full-scale field results. Attenuation through the foliage was seen in both cases: the trees attenuated sound by up to 3 dB in the scale-model tests and 5 dB in the full-scale tests, due to scattering or absorption. However the IL's in the field tests were smaller below and higher above 600 Hz.

In the scale-model results, the trees had very little effect at the receiver in front of the trees. In the field tests, however, sound levels actually decreased in front of the barrier when the trees were present. One reason for this was the change of ground surface between measurements [14]. The tests in the no-trees case were done in the middle of a grass field, while the ground beneath the hedge contained roots which added porosity, increasing the ground absorption. This could also increase the occurrence of attenuation due to foliage in the measurements taken behind the trees. In the scale-model measurements, the ground remained the same, as the removal of the trees did not affect the model ground.

Another reason for the differing results is likely the leaf size; the leaves in the full-scale hedge were much smaller than the full-scale dimensions of the scale-model trees. The full-scale tests were done on an evergreen hedge with much smaller leaves. In contrast, the leaves on the scale-model trees were quite large compared to the wavelength – approximately 2-mm wide, corresponding to a full-scale size of 6 cm. This is a closer model to a broad-leafed tree. Attempts to locate such foliage for testing were unsuccessful.

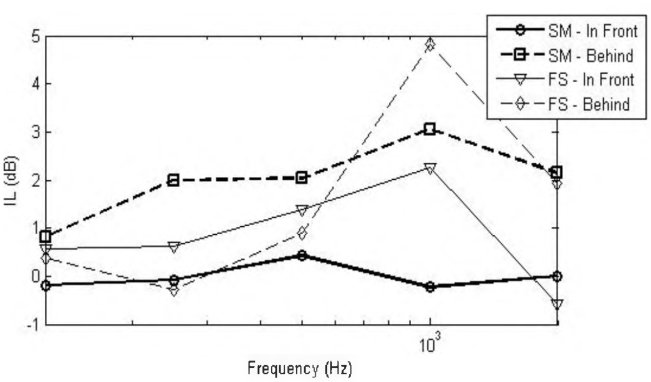


Figure 6. The measured IL in octave bands of a row of trees, measured 5 m in front and 5 m behind the foliage. Full-scale measurements (FS) are compared to scale-model measurements (SM).

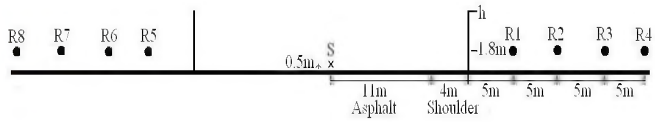


Figure 7. The scale-model test configuration.

The small change due to foliage seen in front of the hedge in the scale-model measurements, where the ground was consistent, and the much greater decrease in sound which reached the back suggested that energy was being scattered or absorbed by the foliage, while little was being back-scattered. The foliage absorbed energy by transferring the sound energy into vibrational energy in the leaves and branches. Sound was scattered in many directions, as opposed to being transmitted through the foliage to the receiver on the other side.

4 RESULTS

Insertion-loss tests were performed using both single and parallel noise barriers. In both configurations, described here using the corresponding full-scale dimensions, a 22-m wide, four-lane highway was modelled. The shoulder – the space between the asphalt and the barrier – was 4-m wide. A distance of 30 m between the parallel barriers was chosen due to the facts that a smaller distance is rarely found in the field, and that the amplification effects are reduced at larger distances. The sound source was placed 0.5-m high, in the center of the highway, 11 m from the shoulder. Receivers were placed 5, 10, 15 and 20 m behind the barrier(s) at a height of 1.8 m. Barrier heights of 3, 4 and 5 m were tested. Figure 7 shows the configuration used.

4.1 Absorption

The effects of barrier absorption on the source side of the barrier were examined for three different barrier heights: 3, 4 and 5 m. Several configurations were measured: reflective and absorptive single barriers, reflective and absorptive parallel barriers, and parallel barriers with one reflective and one absorptive. In the last of these configurations, the reflective barrier was the one between the source and receiver positions R1-R4, while the one between the source and positions R5-R8 was absorptive. When testing one barrier, the barrier between the source and receivers R5-R8 was removed; the IL's for those tests at those receivers were close to zero and are not shown.

Figure 8 shows the octave-band IL at receiver position R2 for the 5-m-high reflective parallel barriers, which ranges from 11-16 dB. Figure 9 shows the IL differences between the reflective parallel barriers and the other barrier and absorption configurations. The IL shown in Figure 7 has been subtracted from the IL's for the other configurations; therefore a positive change in IL is a decrease in noise levels and an improvement in barrier performance. At low frequencies, the effect of adding a second barrier is apparent; the IL is 1 dB higher for a single barrier than for parallel barriers. Here, absorption increased IL by 1 dB for the parallel barriers. At high frequencies, adding absorption to a single barrier increased IL by 1 dB. For parallel barriers, making them absorptive increased IL by up to 3 dB. Adding absorption to one of the parallel barriers improved IL slightly, making the IL just slightly lower than that of a single reflective barrier.

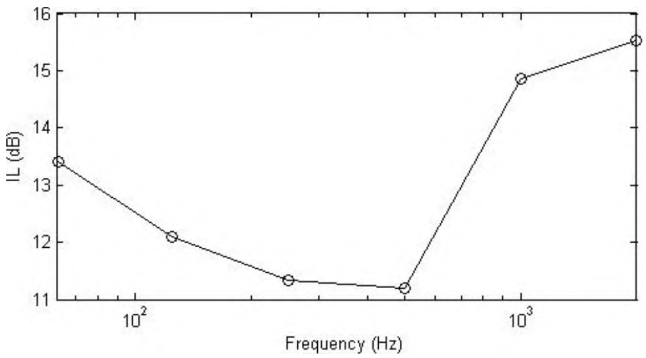


Figure 8. The measured IL in octave bands at receiver position R2 for the 5-m-high reflective parallel barriers.

The A-weighted IL's for the different configurations, at each receiver position and for a barrier height of 5 m, are shown in Figure 10. Changing from a single 5-m reflective barrier to 5-m parallel reflective barriers decreased the IL by approximately 1 dBA. This demonstrates the amplification that occurs between parallel barriers. With absorptive barriers, the parallel barriers gave IL's which were very similar to those of a single barrier. Absorption added to the reflective walls increased the IL very slightly (< 0.2 dBA), but reduced reflections from the wall by up to 1 dBA.

Figure 11 shows the A-weighted IL's for parallel barriers at receiver position R2 for the three barrier heights: 3, 4 and 5 m. Based on these results, increasing the height of a barrier by 1 m increased the IL by more than adding absorption to a smaller noise barrier. By using a best-fit line, it was found that adding absorption increased the IL by the same amount as increasing the height by 0.33 m. This result is specific to these data and not necessarily generalizable.

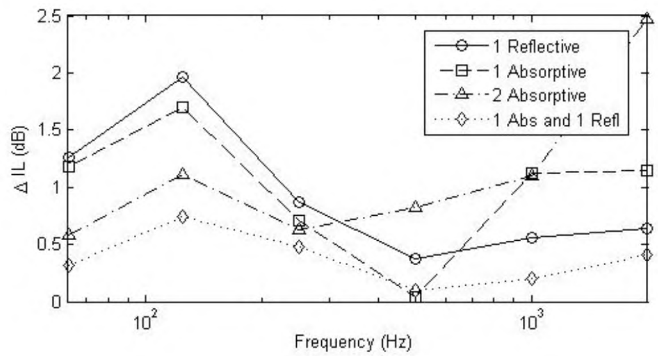


Figure 9. The measured differences in IL between reflective parallel barriers and other configurations. Shown in octave bands and measured at receiver position R2 for the 5-m-high barriers.

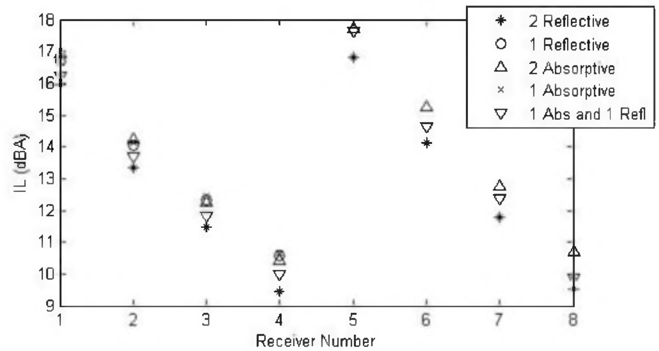


Figure 10. The measured A-weighted IL's for the 5 m tall barriers at the eight receiver positions.

4.2 Foliage: Parallel Barriers

The effect of adding a row of trees along the source sides of 5-m-high parallel barriers is shown in Figure 12. The trees were approximately 5.5-m high, so they overtopped the wall slightly. The measured change in octave-band IL in the case of reflective barriers with and without the rows of trees, measured at position R2, is shown. The foliage had negligible effect up to 500 Hz, then decreased the IL at frequencies up to 1000 Hz. Above this band, the foliage increased IL, acting as a scatterer; sound that would normally reflect from one barrier and diffract around the other is scattered in other directions. Below 1250 Hz, the foliage which overtopped the barrier scattered sound into the shadow zone, causing the decrease in IL.

Figure 13 shows the total, A-weighted IL of reflective and tree-lined parallel barriers at all receiver positions. The trees on the source sides of the barriers decreased the total IL by up to 1 dBA. The increase observed at high frequencies is not enough to balance the decrease below 1250 Hz.

4.3 Foliage: Single Barrier

The effects of foliage at different positions around the barrier were examined using a single, 3-m-high barrier. Only four receiver positions, R1-R4, were behind the single barrier, therefore measurements were taken only at those four positions. The trees were placed at different positions around the barrier: directly behind the barrier, directly in front of the barrier, and 10 m behind the barrier such that

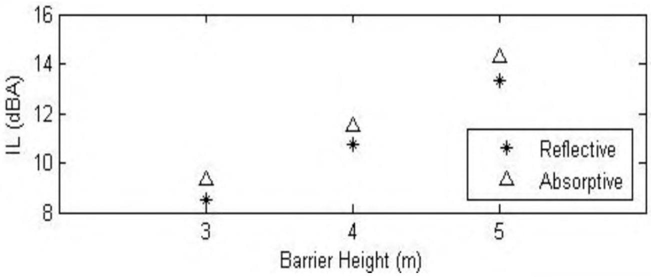


Figure 11. The measured total, A-weighted IL's at R2 for absorptive and reflective parallel barriers of three heights.

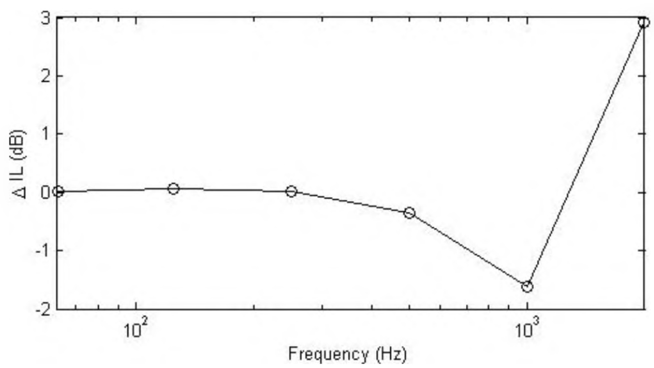


Figure 12. The measured change in IL in the case of parallel barriers with and without a line of trees along the source sides of the barriers. Shown in octave bands and measured at receiver R2 for 5-m-high parallel barriers.

receiver position R1 was between the trees and the barrier. Two different foliage heights were used: 5.5 and 7.2 m. With the taller trees, both the regular density of trees – where the tree bases were placed approximately 1.5 m apart – and with a thicker row of trees – where tree bases were placed 0.9 m apart – were tested. The differences in IL between a reflective barrier and the different foliage configurations are shown in Figures 14 and 15 for the shorter and taller trees, respectively. Placing the foliage directly next to the barrier, either in front or behind, had little effect at low frequency and caused an increase in IL at mid-frequencies. Here the sound was absorbed and back-scattered by the foliage. At high frequencies, the IL decreased by up to 4 dB. At these frequencies, sound was scattered by the foliage into the shadow zone. For taller trees, the attenuation at lower frequencies was greater, and scattering into the shadow zone began to occur at a lower frequency. At low frequencies, the taller trees provided more opportunity for sound absorption and back-scattering, much like increasing the height of a noise barrier. At higher frequencies, there was more effective foliage surface area to scatter the noise. Similar frequency-dependent behaviour has reported been reported in the literature [9, 15]

Placing the trees behind the receiver position had very

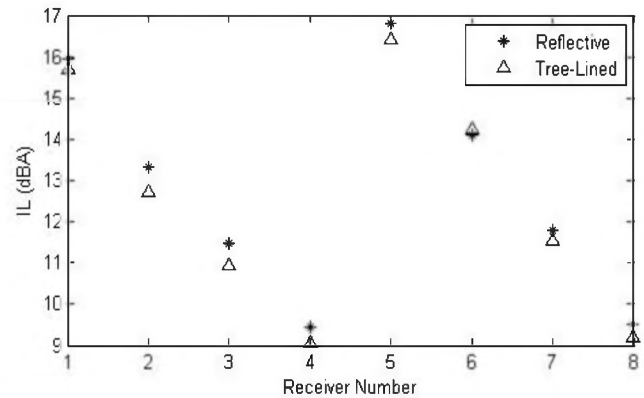


Figure 13. The measured A-weighted IL's for the 5-m-tall barriers at the eight receiver positions, with and without a line of trees along the source sides of the barriers.

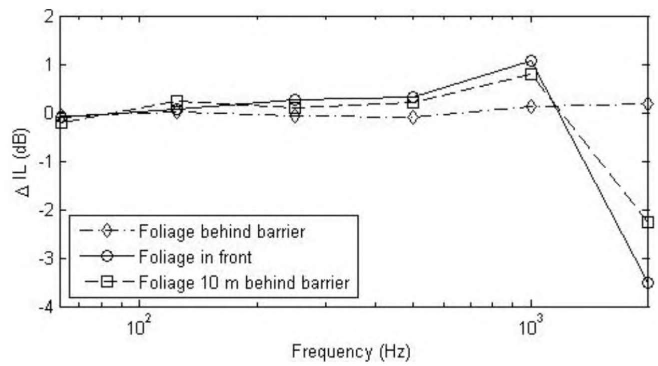


Figure 14. The measured change in IL between a reflective barrier and the different foliage configurations. Shown in octave bands at receiver R1 for a 3-m-high barrier, with 5.5-m-tall trees.

little effect on the IL, in agreement with earlier tests that found little sound is back-scattered from a row of trees. Using denser foliage also had a small effect on the IL. In general, IL increased very slightly, indicating that the denser foliage attenuated more sound, as expected.

5 CONCLUSIONS

A scale model was developed to test two factors that may affect noise barriers. Excess-attenuation measurements were performed to select appropriate model materials. A four-lane highway configuration was then set up, with the option of having a single barrier or parallel barriers. Absorptive barriers of varying height were investigated. It was shown that adding absorption to the source side of parallel barriers increased the total IL by 1 dBA which, in this case, was found to be equivalent to increasing the height of the barrier by 0.33 m. It was also seen that using absorptive barriers prevented the 1 dBA decrease in IL when adding a second barrier, as occurred with reflective barriers. The effects of tree foliage near barriers were also examined using the scale model. Comparisons between measurements done with the scale-model trees and similar measurements done at full scale showed the model trees to be reasonable models of broad-leaf trees. The model trees were then placed in different positions near the barrier. It was seen that foliage directly in front of or behind the barrier scattered up to 4 dB of sound into the shadow zone, causing the barrier to be less effective, at high frequencies. It was also seen that foliage attenuated sound by up to 2 dB, increasing the effectiveness of the barrier, at mid-frequencies.

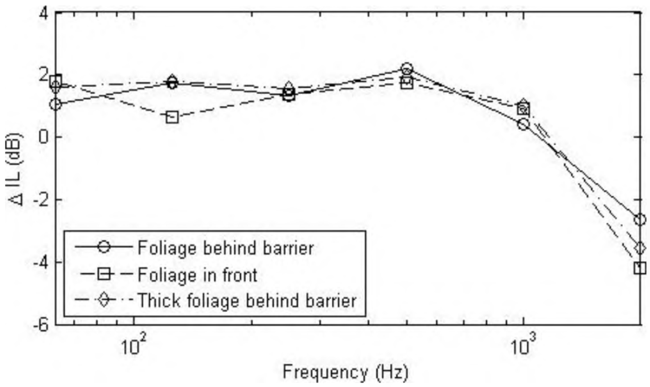


Figure 15. The measured change in IL between a reflective barrier and the different foliage configurations. Shown in octave bands at receiver R1 for a 3-m-high barrier, with 7.2-m-tall trees.

REFERENCES

[1] S. Daltrop, "Investigation of factors affecting the performance of roadside noise barriers", M.A.Sc. (Mechanical Engineering) Thesis, University of British Columbia (Aug 2011).

[2] M. M. Osman, "MTC Scale model facility for transportation noise problems: Materials choice and validation for scale modelling", Technical Report 77-AC-4, Ontario Ministry of Transportation and Communications (1977).

[3] D. N. May and M. M. Osman, "Highway noise barriers: New shapes", Journal of Sound and Vibration 71(1), 73–101 (1980).

[4] C. W. Menge, "Highway noise: Sloped barriers as an alternative to absorptive barriers", Noise Control Engineering 14(2), 74–78 (1980).

[5] D. C. Hothersall, D. B. Horoshenkov, P. A. Morgan and M. J. Swift, "Scale modelling of railway noise barriers", Journal of Sound and Vibration 243(2), 207–223 (2000).

[6] T. Busch, "Scale-model investigation of highway traffic noise barriers", Master's Thesis, Department of Mechanical Engineering, University of British Columbia (1997).

[7] D. I. Cook and D. F. Van Haverbeke, "Suburban noise control with plant materials and solid barriers", In: Heisler, Gordon M.; Herrington, Lee P., eds. Proceedings of the Conference on Metropolitan Physical Environment; Gen. Tech. Rep. NE-25. Upper Darby, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station, 234-241, (1977).

[8] T. Van Renterghem, D. Botteldooren and W. M. Cornelis and D. Gabriels, "Reducing screen-induced refraction of noise barriers in wind by vegetative screens", Acta Acustica united with Acustica 88, 231–238 (2002).

[9] T. Van Renterghem and D. Botteldooren, "Effect of a row of trees behind noise barriers in wind", Acta Acustica united with Acustica 88, 869–878 (2002).

[10] D. A. Hutchins, H. W. Jones and L. T. Russell, "Model studies of acoustic propagation over finite impedance ground", Acustica 52(3), 169–178 (1983).

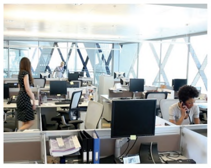
[11] T. A. Busch and M. R. Hodgson, "Improved method for selecting scale factors and model materials for scale modelling of outdoor sound propagation", Journal of Sound and Vibration 243(1), 173–181 (2001).

[12] M. E. Delany and E. N. Bazley, "Acoustical properties of fibrous absorbent materials", Applied Acoustics 25(114), 339–344 (1971).

[13] J. Novak, "Technical note: Sound source for scale-model measurements of traffic noise", Applied Acoustics 24(1), 63–70 (1988).

[14] W. Huisman and K. Attenborough, "Reverberation and attenuation in a pine forest", Journal of the Acoustical Society of America 90, 2664-2677 (1991).

[15] W. M. Schuller and J. H. de Zeeuw, "Acoustic effect of trees on barrier", Proc. Internoise 1981, 253-256 (1981)




Cadna R®

Prediction of
Noise Levels inside Rooms

New: Interior Noise calculation with CadnaR

Cadna R®

Prediction of
Noise Levels inside Rooms

Highlights:

- Intuitive handling
- Efficient workflow
- Unique result display
- Detailed documentation
- Excellent support

Intuitive Handling

The software is clearly arranged to enable you to build models and make simple calculations easily. At the same time you benefit from the sophisticated input possibilities as your analysis becomes more complex. Focus your time on the project and not on the software. All input and analysis features are easy and intuitive to handle.

Efficient Workflow

Change your view from 2D to 3D within a second. Multiply the modeling speed by using various shortcuts and automation techniques. Many time-saving acceleration procedures enable fast calculations of your projects.

Modern Analysis

CadnaR uses scientific and highly efficient calculation methods. Techniques like scenario analysis, grid arithmetic or the display of results within a 3D-grid enhance your analysis and support you during the whole planning and assessment process.

Further informations at www.Datakustik.com

DataKustik

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