ADDRESSING THE EFFECTS OF OVERTOPPING VEGETATION ON THE PERFORMANCE OF HIGHWAY NOISE BARRIERS

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1. INTRODUCTION

The reflection and scattering of mid and high-frequency sound by vegetation may be observed in a number of familiar situations. For example, the reflection of tire noise when driving an open car beneath the overhanging branches of broad-leafed trees or the echoing of shouts or gunshots from the edge of a forest. Generally these phenomena have little broader relevance. However, where vegetation is close to and overtops a highway noise barrier, it will tend to scatter sound down behind the barrier thereby reducing its insertion loss, particularly at higher frequencies. Not only is the A-weighted insertion loss of the barrier reduced, but on its "shielded" side, traffic noise no longer sounds "muffled" because its high-frequency content has not been sufficiently attenuated. Therefore, while the barrier may still be providing a worthwhile reduction in the A-weighted sound level, the listener's impression may to be that the barrier is having little or no effect. This phenomenon may have significant implications for the success of highway noise mitigation programs, particularly where the source-receiver geometry makes it challenging to achieve substantial noise reductions and when it is necessary to confirm the barrier's performance (insertion loss) through post-project field measurements.

Drawing on the very limited quantitative research that appears to have been done on this subject, this paper will assess the effects of sound scattering by overtopping vegetation on highway noise barrier performance and discuss ways in which they might be addressed, either physically or administratively. The interaction between pavement design (e.g. quiet pavement) and vegetation scattering effects is also explored.

2. M.I.T. SCALE MODELING STUDY

The only previous investigation found to have focused specifically on the effects of overtopping vegetation on the insertion loss of noise barriers was based on scale model studies [1] conducted by Christopher N. Blair at M.I.T. Key results of this work were summarized in a 1977 paper by Richard H. Lyon, Blair, and Richard G. DeJong [2]. The scattering effects of scale model broad-leafed trees, placed to one side of, and then directly above a noise barrier, were measured in a 1:20 scale model facility using an electric spark discharge as the sound source.

These scale-model results have been used herein to estimate the potential effects of overtopping vegetation on highway noise barriers which, in the absence of such vegetation, would provide insertion losses ranging from 5 to 15 dBA.

Figure 1, from Lyon, shows the generalized effects of vegetation scattering on sound levels both with and without a noise barrier present.

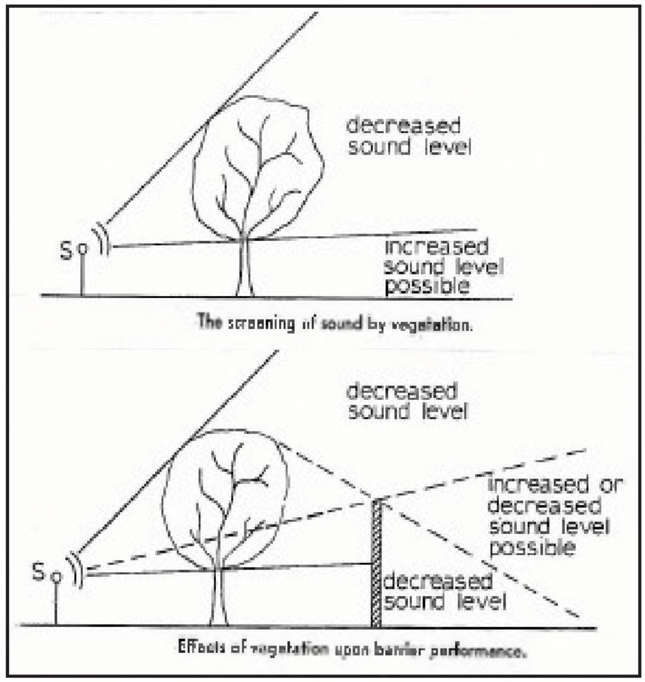
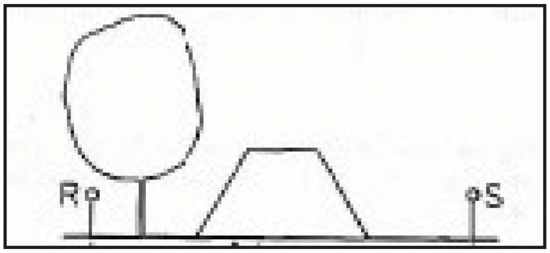


Figure 1; Generalized Effects of Vegetation Scattering

It is seen that vegetation, particularly broad-leafed trees, can either reduce or increase sound levels at a distance from a broad-band source depending on the location of the receiver relative to the vegetation (e.g., crowns of trees), the ground (assumed acoustically soft) and the barrier if present.

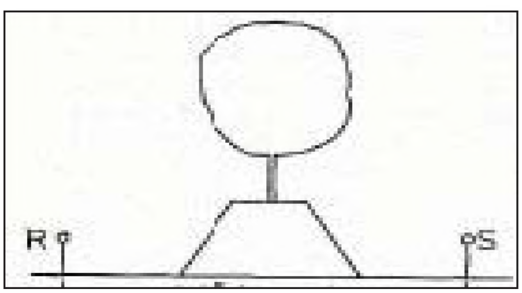
Figure 2 shows the scale-model configuration with 9 m maple trees located to one side of an approximately 3.5 m high earth berm. The sound receiver is located beneath the tree while the source is on the far side of the berm. The accompanying graph shows the measured attenuations (insertion losses) in one-third octave bands both with and without trees present. It is seem that the effects of tree scattering ranged from 2 to 7 dB at mid frequencies (630 to 1,250 Hz.) and reached 12 dB at 4,000 Hz.



630 Hz.	800 Hz.	1.0 kHz.	1.25 kHz.	1.6 kHz.	2.0 kHz.	2.5 kHz.	3.15 kHz.	4.0 kHz.
11	14	21	23	24	19	24	24	30
9	8	16	16	15	12	17	15	18
Δ =2	6	5	7	9	7	7	9	12

Figure 2; Attenuation of Sound by Barrier Without (upper row) and With (middle row) Broad-Leafed Trees along One Side. Difference (bottom row).

Figure 3 shows the modeled configuration with 9 m maple trees located directly on top of the earth berm with the sound source and receiver located on opposite sides of the berm. The accompanying graph shows the measured attenuations both with and without trees present. It is seen that the effects of tree scattering can reach 10 to 14 dB at mid frequencies and exceed 20 dB at 4,000 Hz.



630 Hz.	800 Hz.	1.0 kHz.	1.25 kHz.	1.6 kHz.	2.0 kHz.	2.5 kHz.	3.15 kHz.	4.0 kHz.
11	14	21	23	24	19	24	24	30
1	3	9	8.5	8.5	3	9	7	9
Δ=10	11	12	14.5	15.5	16	15	17	21

Figure 3; Attenuation of Sound by Barrier Without (upper row) and With (middle row) Broad-Leafed Trees on Top. Difference (bottom row).

3. APPLICATION OF SCALE MODELING RESULTS TO HIGHWAY NOISE

3.1 Traffic Noise Spectra

To explore the effects of tree scattering on highway noise specifically, a noise spectrum measured beside Highway 19 in Nanaimo, B.C. was used. At the time (1995) this highway featured somewhat worn, standard hot-mix asphalt pavement and carried roughly 2,500 vehicles per hour (with 5% heavy vehicles) at an average vehicle speed of 75 kmph. This traffic flow generated an equivalent sound level of L_{eq} 75.5 dBA at a distance of 15 m from the centre of the near lanes while its spectrum peaked at 1,000 Hz. This section of highway was later paved with open-graded asphalt (OGA) as part of a "Quiet Pavement" assessment. The traffic noise generated with OGA pavement contains less energy at middle and high frequencies so that it less susceptible to scattering by vegetation.

3.2 Vegetation Scattering Effects with Standard Asphalt

To estimate the effects of vegetation scattering on barrier performance against traffic noise generated on standard asphalt, the scale-modeled barrier attenuations from Figures 2 and 3 (with and without trees) were applied to the highway noise spectrum described above and the overall A-weighted insertion losses calculated. In the absence of trees, the scale model earth berm was able to reduce the traffic noise generated on standard asphalt pavement by 15.5 dBA. With 9 m maple trees located to one side of the berm and above the receiver position (Figure 2), the earth berm's performance was reduced by about 2 dBA to 13.4 dBA. However, with trees located directly on top of the berm (Figure 3), its insertion loss was reduced by 8.5 dBA, from 15.5 to 7.0 dBA.

At 15.5 dBA, the scale model earth berm's highway noise insertion loss in the absence of trees is near the upper end of the range typically observed in the field - the berm's effectiveness being enhanced by its nearness to both noise source and receiver. It is of interest to examine the effects of vegetation scattering on noise barriers having more typical capabilities – i.e., those providing insertion losses of between 5 and 10 dBA in the absence of vegetation. It was assumed that the sound intensity at the receiver location behind the barrier due to scattering alone would be the same for all cases. The level of scattered sound behind the barrier was then estimated from the insertion loss-degradation effect caused by the maple trees located directly on top of the scale model earth berm. The procedure was as follows.

Arbitrarily assume that the traffic noise level at the receiver with neither barrier nor trees present is 70 dBA. Therefore when a nominal "15 dBA" noise barrier is inserted, the receiver level will drop by 15 dBA to 55 dBA with this residual sound level being attributable to the diffracted sound field behind the barrier. Since it was found above that tree scattering reduced the insertion loss of the scale model earth berm by about 8 dBA, when such trees are placed above our nominal "15 dBA" barrier, its insertion loss will be reduced from 15 to 7 dBA. The noise level at the receiver in the presence of such trees would then become 70 – 7 = 63 dBA. The level of scattered sound behind the barrier can therefore be estimated as the logarithmic difference between the receiver level with and without trees, that is 63 minus 55 dBA, or 62.3 dBA. It was then assumed that this same level of scattered sound would