Uncertainty in Prediction of Environmental Noise Immission due to Ground Effect

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INTRODUCTION

Prediction of sound levels at noise sensitive receptor locations for the purpose of verifying compliance with limits set by an approving agency is a necessary part of the design of a new industrial plant or other noise emitting facility.

One of the main factors influencing outdoor sound propagation, aside from distance attenuation, acoustic shielding, and atmospheric effects is ground absorption loss commonly called "ground effect" which depends in a complicated way on the source-receiver geometry, atmospheric turbulence and their random variations, as well as on the characteristics of the ground surface and the terrain topography.

The effect of ground on acoustic propagation has been thoroughly investigated in the last decades. A large number of theoretical papers have been published on this subject with a broad range of differing results and opinions, and a number of empirical models have been developed to assist in sound level prediction. However, engineering applications are scarce and international standards have not been developed as yet.

Uncertainties in prediction of ground effect along the path from noise sources to distant receptors may have serious implications on the recommended separation distance or the extent of other noise mitigation measures designed to ensure compliance. The results of noise impact assessment for a proposed noisy facility based on a procedure predicting unrealistically high values of ground attenuation may prompt an approval agency to recommend a relatively small separation distance between the facility and noise sensitive receptors which will lead to excessive sound levels and, consequently, to an adverse community reaction. Conversely, an assessment based on an assumption of very low ground absorption loss contribution may result in specification of a large buffer zone and, consequently, the sterilization of land available for development, or to excessive noise abatement recommendations directed at the source to ensure compliance.

EXISTING STANDARDS

According to (10), Clause 1.2, weather conditions (principally temperature inversions and the following winds) common in temperate climates considerably reduce ground effect and therefore prediction of this sound attenuation component is not part of the standard. However, it is advised in the same clause of the standard, that if ground effect is to be considered, a simple approach using the difference in propagation between hard and soft ground given in Table 3.5 of the CMHC Publication "Road and Rail Noise. Effects on Housing" can be applied.

MODEL COMPARISON

At present, prediction of attenuation due to ground effect at the design stage is done by a variety of approaches with some similarities. The prediction models developed to include an estimate of ground absorption loss component of sound attenuation are based on a combination of theoretical considerations and empirical experience. They vary in complexity and may provide broadly differing ground effect values.

Simplified Models

The simplified prediction schemes allow for prediction of ground attenuation as a function of distance and a mean effective height of sound propagation path above the ground along the distance from source to receiver location, and are applied to calculations of the A-weighted sound level due to traffic noise having a predominant frequency component in the spectrum at 500 Hz.

Figure 1 provides a comparison of results obtained using four simplified ground attenuation prediction models (1),(2),(3),(4) for a range of distances from 100m to 300m and one configuration of source and receiver heights of 1.5m. Models in (1) and (2) are well established and widely used, while model in (4) represents a proposal in the draft international standard ISO/DIS 9613. Model in (3) was developed based on experimental results reported in (5).

Comprehensive Models

These models allow for the calculation of ground effect as a function of frequency. Acoustical characteristics of ground surface between source and receiver, in terms of flow resistivity or a ground factor, is included in the prediction. Although, in general, a homogeneous ground surface is assumed, provision is made in some models for two or three different ground surface characteristics for surface areas close to source, central part and close to receptor, with specific boundary conditions.

A comparison of results for three models (6), (7), and (8) which allow for the calculation of ground effect as a function of frequency is shown in Figure 2. Here, a typical broad band spectrum of a diesel engine was assumed, and ground effect values were calculated in one octave frequency bands. The assumed source spectrum was adjusted for the calculated ground effect values for each model, and A-weighted values calculated for the range of distances from 300m to 1000m. Source and receiver configuration (H_s=3m, H_r=1.5m) over flat ground was selected to accommodate the range of parameters in the models subject to the comparison, and an acoustically porous grass covered ground surface was assumed.

Results of spectral analysis for three models (7) (8) and (9) are compared in Figure 3 for distances 300m and 800m respectively at a configuration of source and receiver, H_s=H_r=1.5m over flat, grass covered ground surface. S. SPECT. in the legend denotes frequency spectrum of a diesel engine. The remaining three spectra in Figure 3 represent reductions due to ground attenuation calculated from the respective three models (7), (8) and (9).

CONCLUSIONS

Propagation conditions in terms of atmospheric parameters may be principally responsible for a relatively large variation in results obtained using different models. Model (7) represents theory of interference and ground-wave effects, while (6) and (8) were developed from empirical data collected under specific set of wind and temperature gradient propagation conditions downwind. Model (9) is based on field data obtained under "favourable weather conditions"

A similar conclusion can be drawn from the comparison of results in Figure 1 for the simplified models.

In general, the comparison of models reveals significant variations in the predicted values of ground attenuation, which may seriously compromise the reliability of noise impact assessments. A uniform standarized procedure for assesing the ground effect component of sound attenuation is clearly needed.

The ground attenuation model presented in (8) is currently included in the draft standard ISO/DIS 9613 which is subject to an ongoing review by the ISO Working Group 43.

REFERENCES:

1. Halliwell R. E., and Quirt J. D. Traffic Noise Prediction. National Research Council of Canada, Division of Building Research, BRN 146 (1980).

2. ORNAMENT, Ontario Road Noise Analysis Method for Environment and Transportation. Ontario Ministry of the Environment (1989).

3. Private correspondence with R. Andrews. July 14, 1993.

4. ISO/DIS 9613, Acoustics - Attenuation of sound during propagation outdoors - Part 2: A general method of calculation (1992)

5. Parkin P. H. and Scholes W. E. The Horizontal Propagation of Sound from a Jet Engine Close to the Ground, at Hatfield. J. Sound Vib. 2 (4), 353-374 (1965)

6. Beranek L. L. Noise and Vibration Control, Revised edition. Institute of Noise Control Engineering (1988)

7. Embleton T. F. W., Piercy J. E. and Olson N. Outdoor Sound Propagation over Ground of Finite Impedance. J. Acoust. Soc. Am., Vol 59, No 2, 267-277 (1976)

8. Kragh J., Andersen B., and Jakobsen J. Environmental Noise from Industrial Plants. General Prediction Method. Danish Acoustical Institute. Report No. 32, Lyngby (1982)

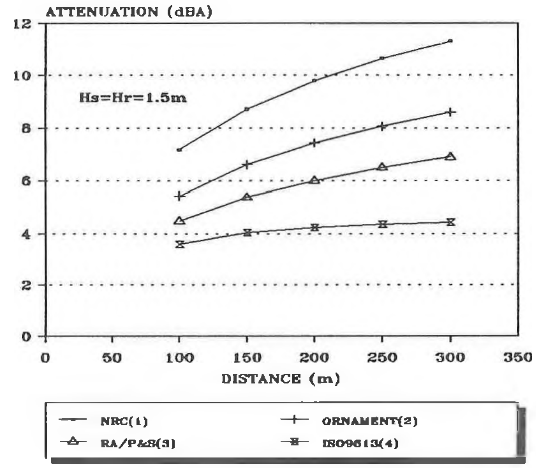
9. Harris C. M. Handbook of Noise Control (1979)

10 Embleton T. F. W. Sound Propagation Outdoors - Improved Prediction Schemes for the 80's., 17-30, Inter-Noise 80

11. Canadian Standard CSA-Z107.55-M86, Recommended Practice for the Prediction of Sound Levels Received at a Distance from an Industrial Plant.

12. Kragh J. Noise from Industrial Plants, Measurement and Prediction. Final Report from a Nordic Co-operative Project. Nordic Methods for Measurement and Prediction of Environmental Noise from Industrial Plants, NORDFORSK (1984)

FIG.1 GROUND ATTENUATION VS. DISTANCE COMPARISON OF MODELS/TRAFFIC NOISE



FIGU.2 GROUND ATTENUATION VS. DISTANCE COMPARISON OF MODELS/SPECT.TO dBA

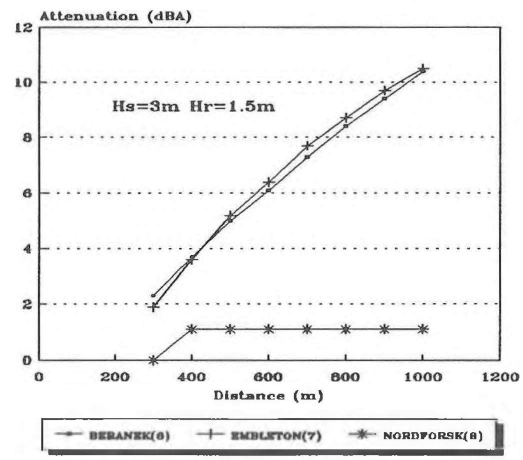


FIG.3 GROUND ATTENUATION VS. FREQUENCY COMPARISON OF MODELS, D=300m