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GROUND EFFECT AND SURFACE TRANSPORT NOISE PREDICTION

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Introduction

The current U. S. Department of Transportation Federal Highway Authority prediction scheme (1) requires that an excess attenuation of 1.5 dB per doubling of distance (dd) be applied where the highway noise travels over acoustically 'soft' terrain, e.g. grassland but with a height restriction to mean propagation heights less than 3 m. A similar correction is advocated in the currently accepted prediction scheme in the U.K. (2) Recent measurements of highway noise propagation in the U. S. A. (3) (intended to verify the current prediction scheme), in which wind speed and direction were monitored carefully indicate that 1.5 dB/dd excess attenuation is a good average over 'soft' terrain which is flat, free from snow and predominantly covered with cut grass but that site-to-site uncertainty could be more than 5 dB/dd. Furthermore, the attenuation rate per dd was found to be dependent on distance from the source. The wind speed during most of the data collection was less than 5 m.p.h. So the uncertainty in excess attenuation must be due to refraction, turbulence or site-to-site variation in ground effect. This paper explores the last of these possibilities.

Theory of Point-to-Pont Propogation

Recent work (4) indicates that reasonable agreement with observed data of the excess attenuation from a point source over an absorbing ground vs. frequency and distance can be obtained using a theory which assumes the ground surface is locally reacting and which produces a solution for the total field which consists of a direct wave, a reflected wave, a ground wave (analogous to the wave responsible for AM radio reception) and a surface wave (which exists only under certain conditions dependent upon grazing angle and the relative values of the real and imaginary part of normal surface impedance). The surface wave is particularly important at low frequencies, and long ranges (near grazing incidence) over grassland. Discrepancies between theory and observation at high frequencies which may be due either to uncharted turbulence during the measurements or to the assumption of local reaction in the theory are not likely to be significant in predictions of 'A' weighted sound levels.

Impedance Data and Models of the Ground Surface

Outdoor in-situ measurements of high impedances are particularly difficult to make. Thus, there are few reliable data. Measurements using both a vertical impedance tube technique and an inclined-track (oblique-incidence)

*Some of the work reported here was performed while the author was on study leave at The Noise Control Laboratory, Dept. of Mechanical Engineering, The Pennsylvania State University.

technique on 'institutional' grass were made at the National Research Council of Canada. The general trend of impedance vs. frequency shown by these data is supported by recent impedance tube measurements made at the University Farm of The Pennsylvania State University. They are supported further by impedance vs. frequency values deduced by Thomasson (5) for grassland by means of a local reaction theory from excess attenuation vs. frequency measurements over a relatively short range. Significantly, different impedance vs. frequency variation for grassland has been reported by Dickinson and Doak (6) who also report measurements over gravel and sand. Although several similar sites at Penn State yielded impedance data conforming to the NRCC trend, other sites indicated significantly different impedances; the main variation being in the imaginary part of impedance. Data similar to that of Dickinson and Doak (6) for grassland was produced at Pennsylvania State University by a small number of grass sites and by measurements on a weather slaked ploughed field. It has been shown that measured impedance data for grassland can be reproduced either by an empirical model relating relative characteristic impedance to flow resistance and frequency (based upon data for porous fibrous absorbents) (9) or by a simplified four-parameter model for the normal surface impedance of a porous rigid-framed layer (5, 10).

A common assumption of prediction models is that asphalt and other similar surfaces are perfectly reflecting. Recent measurements (7) however show that the admittance of asphalt although small is sufficient to produce a 1-2 dB error in predicted sound levels at short range (15 m) if the surface is assumed to be perfectly reflecting. This has particular significance for models of the road surface/soft terrain boundary baffle effect (4, 8).

Effect of Impedance Variation on Sound Propagation

The major difference between the predictions of excess attenuation vs. frequency using the local reaction solution with both the NRCC and the Dickinson and Doak impedance data is at frequencies below 800 Hz. (It should be noted that the NRCC values give better agreement with measurements for the chosen configuration). The form of the difference is similar to that observed in propogation over a ploughed field before and after disking.

Predictions of highway noise attenuation as a result of varying the imaginary part of the ground impedance by a factor of two in the local reaction solution vary by 2-3 dB for distances from 20 m to 600 m from the source.

Conclusions

Predictions of highway noise attenuation (in the absence of micro meteorological effects) are sensitive to site-to-site variations in ground impedance. Furthermore, the ground effect departs from a uniform attenuation per doubling of distance to an extent that warrants a careful reappraisal of the expected accuracy and provisions of current prediction schemes. The sensitivity described above implies a requirement for more accurate measurements of impedance and a classification of surfaces.

GROUND EFFECT AND SURFACE TRANSPORT NOISE PREDICTION

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4. 1978 Sound Propagation Over Absorptive Ground Planes, Draft Report, Contract No. DOT-FH-11-9515

5. S. I. Thomasson 1977 J.A.S.A. 61 (3), 659-674 Sound Propagation Above a Layer with a Large Refractive Index

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7. P. A. Mansbach and C. I. Holmes 1978, Report No NBSIR 78-1541 USEPA Techniques for the Measurement of Acoustic Impedance of Asphalt

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EFFECTS OF HIGHWAY AND URBAN TRAFFIC NOISE ON RESIDENTS

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1. Introduction

The aim of this study was to quantify the annoyance reactions of residents to highway noise using an annoyance component system develloped in a former field study (Kastka 1976, Kastka and Buchta 1977a, 1977b). Furthermore it was intended (1) to relate the annoyance data to the acoustic level of highway noise, (2) to compare the highway noise effects with the annoyance effects of urban road traffic measured within another study on noise annoyance,(3) to study the influence of house type, of (4) position of rooms within the flat relative to the highway and (5) the effect of distance of dwellings to the highway on the annoyance reaction.

2. Method of Investigation

With a standardized questionnaire 359 residents living at 5 selected areas nearby highways were interviewed within their houses. At each of the areas 2 to 4 samples of residents were drawn in clusters in systematically varied distances to the highway (range: 20 - 200 m). The measured noise level L_D outside the houses ranged from 50 to 73 dB(A). Measurement of noise was conducted on basis of DIN 45642. The singel annoyance response variables were combined to 3 components measures, according to factor analytic results of a former field study on traffic noise (Kastka 1976, Kastka and Buchta 1977a+b). By the socalled "sensoric" component the sensory experiences on highway noise (e.g. intensity, quality, frequency and duration of noise) are measured; by the 2. socalled "emotional-somatic" component those variables are combined, which indicate negative emotional excitement, impairment of sleep and recreation, interference with social activities and somatic disturbances (headake) attributed to annoyance. The 3. socalled "acoustic" component integrates those responds variables for interference of noise with communication (speech, television, radio). While the first component thematically is related on stimulus properties of the noise, the second is concentrated on the subject centered effects of noise and the third component is centered on the specific effects of traffic. Alltogether these variables make up a set of 34 items within a 150 item-questionnaire for environmental effects on residents.

3. Results

Significances and stability of motorways annoyance reactions:
From the individual values for every sample a mean value on these components was computed. The correlation coefficients for the subjects mean annoyance reaction and the highway noise level are

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all significant, the degree of relationship is not unsatisfying (tab. 1, 1. row). The noise annoyance reaction of the same residents was assessed in the same way with regard to traffic in their residential street and component values were correlated with the L_D of the motorway noise level.

Table 1: Validity and Reliability of Component Scores (x= r is insignificant)

	Sensor.AR	Som.-Emot.AR	Acoust. AR
L_D and Highway AR N = 15	0.69	0.77	0.69
L_D and Residence street AR N = 15	0.15^x	0.10^x	0.17^x
Reliability of AR N = 71	0.82	0.84	0.76

As expected, no significant relation was found; this is an indication therefore, that residents do not confuse their experiences, but can distinguish between different systems of traffic noise. A second interview after 4 month with 71 subjects within one of the 5 areas was conducted to prove the reliability of the measurement technique. The individually computed test-retest stability coefficents for the 3 components are rather satisfying (3. row of tab. 1).

4. Comparison of motorway and urban traffic noise annoyance reaction

Data from 274 urban residents living in 8 streets were gained with similar methodology and computation procedures. The main result is, that highway noise produces more intensive annoyance effects than urban traffic noise; the greatest differences can be found on thevariables of the stimulus-centered socalled "sensoric" component. At the lower part of the noise level continuum the difference is at maximum: here motorway noise has an annoying effect equivalent to an urban street noise level 15 dB higher than motorway noise (fig.1) At the higher L_D level the difference amounts to 5 dB. For the emotional-somatic and for the acoustic component differences were similar in direction but diminished in extent. The comparison of single response variables of the first component revealed, that the perceived intensity of traffic noise was similar for highway and urban streets. But referring to subjective duration of noise the highway residents experienced the continuity of highway noise in a more intensive way than urban residents did. Even at the lowest level of highway noise the impression of a continous noise source dominates, while at the comparable urban street level the residents have the impression of occasional traffic noise events only. Possibly the different time characteristic of highway noise events compared with urban street noise events is one of the reasons for different disturbance effects: highway noise is always present, urban street noise of the lower level is only an occasional event. The impression of a calm time periode os not existing for residents near highways.

5. Effects of house type: All residents were classified according to the housetype they were living in; the relationsship of the annoyance component to the noise level L_D for the different house-types showed no systematic tendency. Neither the one-familiy-house nor the four-floor-house-type with many flats or one of the other types showed systematic tendencies.

6. Effects of roomposition relative to the highway: the living- and bedrooms of residents were classified according to the position of their windows relative to the highway: 1. in front and parallel to the highway, 2. parallel but on the opposite side of the house, 3. in a 90 degree position to the highway. For the three different types of positions and rooms the relation between component values and L_D were analyzed. The largest effect was found for common position of sleeping- and livingroom in front position, compared to common opposite position of both rooms (fig.2). The opposite vs. front position of the sleepingroom showed higher difference than analogue positions for the livingroom. Residents with sleepingrooms in front of the highway were higher annoyed than residents with livingrooms in front of the highway . The 90 degree position of the window of a room was in all aspects similar to the front position. This means, that this position has no protective function. One can conclude, that for protective functions and annoyance reducing purposes at least one room in a flat should be positioned at the opposite side of a house near by highways.

7. Effect of distance: For all residents the smallest distance between the houses and the highway was computed. The relationsship between distance and mean values of annoyance reactions to highway noise for all distance classes are shown in fig.3. Likewise the functions for annoyance reactions to the residents street traffic noise are plotted there. In a distance of a least 300 m highway noise is experienced as disturbing in an equivalent way as the residents street noise (sensory component values). At a distance of at least 200 m the noise of highway is equivalent to the subject centered emotional-somatic and acoustic disturbances of the residents street noise (component 2 and 3). In a distance about 100 m to the highway 50 % of the respondents rate the situation as unbearable (fig. 4); at this distance about 30 % of the respondents are ready to complain about the motorway noise. These and other data indicate, that at a distance of about 100 m from highway the traffic noise annoyance reaction reveal as all symptoms of a serious environmental stress; at least a distance of 200 m seems to be necessary to protect residents again untolerable consequences of highway noise.

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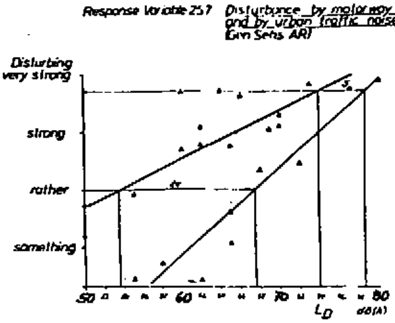

Fig.1: Disturbance by highway and by urban traffic noise

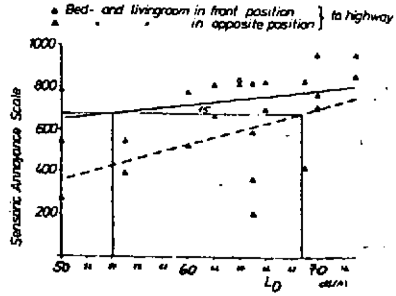

Fig.2: Effect of common position of bed- and livingroom "in front to highway" and in "opposite side" on annoyance

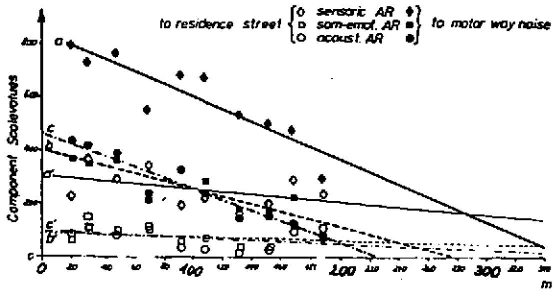

Fig.3: Distance of residents house to highway and annoyance components to highway (a-c) noise and residents street noise (a' - c')

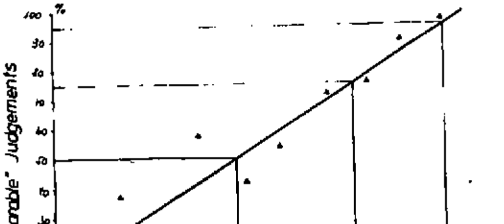

Fig.4: Distance of highway and tolerability of highway noise