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SCALE MODELLING OF TRAFFIC NOISE PROPAGATION IN A CITY STREET CANYON

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1. INTRODUCTION

In spite of a considerable rise in computer performance and the accelerating development of sophisticated numerical methods, traditional scale modelling techniques are becoming increasingly popular for predicting outdoor sound levels. The interest in this relatively simple and inexpensive technique is largely attributed to the growing concern among the public and environmentalists with traffic noise pollution. The high levels of traffic noise pollution are no longer regarded an exception even in small towns and rural communities around the world.

In this paper we discuss some results from the modelling traffic noise in cities conducted at the scale 1:20. The principal aim of the experiments was to investigate the so-called canyon effect when noise is emitted by traffic in the vicinity of the impedance ground and repeatedly reflected from two parallel building facades (see Figure 1). This phenomenon has been poorly understood and received some consideration in the past. Earlier studies [1-5] have mainly focused on the problem of predicting the attenuation of sound propagating from an individual vehicle along the street and contained limited information on the actual effect of multiple reflections on the performance of absorbing surfaces and road noise barriers.

2. THE EXPERIMENTAL MODEL

To study the multiple reflection and scattering effects and the efficiency of different noise abatement schemes a 1:20 scale model of a canyon (Figure 1) has been set up in the anechoic chamber in the University of Bradford. The model had flat rigid floor and two parallel walls sitting upon it.

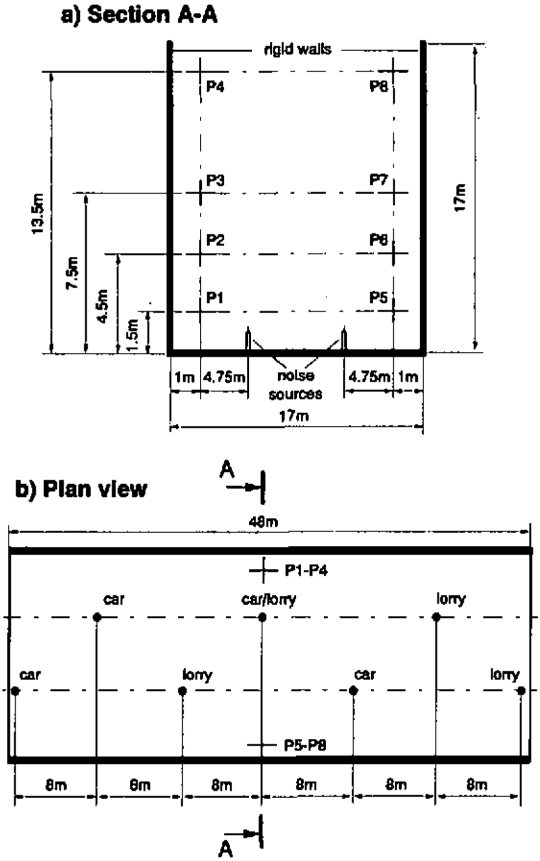

Figure 1. Full scale diagram of the experimental model.

All the rigid surfaces were made of 18mm thick panels faced with Fomica to ensure good reflection of sound in the extended frequency range. The maximum extent of the model was mainly limited by the dimensions of the chamber itself and by the increasing values of the air absorption at ultrasonic frequencies. Several arrangements of absorbers and pedestrian restraints (low profile barriers) were selected for the study and organised as individual experimental designs 'modes' (see Table 1). Careful consideration was given to the selection of materials which could model the acoustic behaviour of some common porous absorbers [6]. Eight receiver positions P1-P8 were introduced (Figure 1 (a)) at 1m from the building facades to investigate the vertical distribution of the noise levels radiated by the vehicles travelling in the near side and far side lanes. Seven ultrasonic sources were distributed along the road to generate noise from traffic on the opposite lanes (Figure 1 (b)) and to allow the investigation of the effect of distance decay. A new type of ultrasonic air-jet source was designed and used to study noise propagation from different categories of vehicles [7]. To model the noise emission from a car and a lorry the sources were elevated above the ground at 0.5m and 1.0m, respectively. The spectrum of every source (2 - 80 kHz) was numerically adjusted during the postprocessing to comply with standard light and heavy vehicle spectra at 1m (100 - 4000 Hz). The levels obtained for every experimental mode were compared to the reference data measured in the case of sound propagation over a rigid ground between two parallel rigid walls (Mode 1 in Table 1). From this comparison the insertion losses were deduced. The latter indicated the quality of the abatement methods tested.

Table 1. Experimental modes.

Mode No	Mode Code	Treatment	Absorbers
1	gr/wr	none	none
2	ga/wr	ground	Coustone
3	gr/wai	walls	felt
4	ga/wai	ground/walls	Coustone/felt
5	gr/br	barriers(r)	none
6	gr/ba	barriers(a)	felt
7	ga/ba	ground/barriers(a)	Coustone/felt
8	ga/wai/ba	ground/walls/barriers(a)	Coustone/felt/felt
9	gr/wai/br/bc	ground/walls/barriers(a/c)	Coustone/felt
Abbreviations:	(r) - rigid side barriers (a) - absorbing side barriers (a/c) - absorbing central reservation barriers.		

The data acquisition system was based on an Elonex PC 466 with an internal WorkMate analog/digital input/output card. The analog input was carried out at 200 kHz sampling rate and up to 16K of samples in floating point format were saved in an ASCII file during a single run. Seven digital I/O channels were used to control seven pneumatic solenoid valves through which the compressed air was delivered to the sources. Only a single source was activated at a time. The acquired data was recorded and later processed. The contributions from individual sources were accumulated and combined numerically.

The acquired time series were either FFT processed or filtered in 18 1/3 octave spectrum bands. A 1/8" 4138 B&K microphone with 2610 amplifier and KEMO VBF 10M anti-aliasing analog filter were used. The mean microphone sensitivity between the normal and tangential directivities was assumed in numerical spectral processing.

3. VALIDATION OF THE MODEL

The model was validated by comparing the results from the experiments with the predictions from the 3-D image source method (ISM). Only simple configurations of two rigid parallel walls and an impedance ground were used in the comparison. Because of many reflected paths contributing to the sound field in the model, compensation for air absorption could not be carried out simply and was accounted for in the ISM to allow comparison.

The contributions from the ground reflections in the ISM were represented using the Thomasson model for sound propagation above an impedance ground. The original expressions given by this model [8] were modified to include the effect of externally reacting ground. The boundary layer effect for the absolultely rigid ground was also considered.

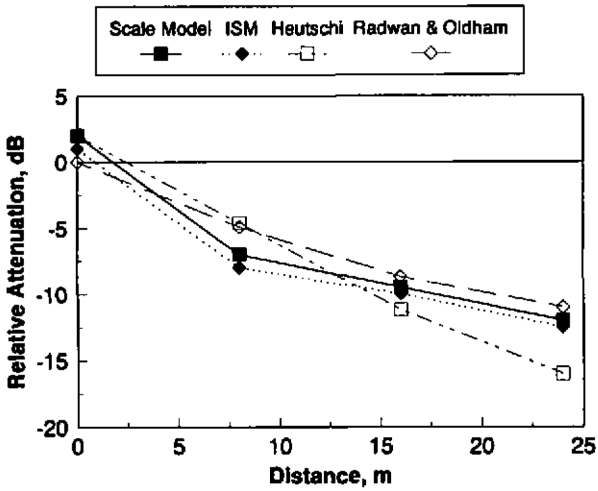

Figure 2. Comparison of data for a car passing along a road. Microphone level P1 and P5.

In Figure 2 a comparison is made between the present work and other published results [4, 5] for the relative attenuation along the canyon. These are only available for configurations with rigid ground and rigid walls, but some results for staggered facades can also be found. The model agrees reasonably well with the ISM results and with the results of other workers.

4. EXPERIMENTAL RESULTS

Starting with the model street with rigid surfaces, various abatement methods were simulated. The basic experimental approaches considered were: a) the use of porous road (Mode 2), b) the use of absorbing materials on building surfaces (Mode 3), and c) the use of pedestrian restraint barriers for noise abatement (Modes 5 and 6). Combinations of these approaches were also assessed (Modes 4, 7-9). The results were presented in the form of an insertion loss, defined for every experimental mode m as:

$$IL_{mi} = SPL_{m1} - SPL_{mi}$$

where SPL_{m1} is the sound pressure level at a given receiver position resulting from two simulated traffic streams on the roadway when all the surfaces are rigid and SPL_{mi} is the sound pressure level at the same receiver position with a given noise abatement treatment characterised as mode i (see Table 1). Figure 3 presents the insertion losses averaged over every floor. The numbers which appear above the bars on the graph are the overall energy mean of the insertion losses over all the eight receiver positions and the legends stand for the mode code (see Table 1).

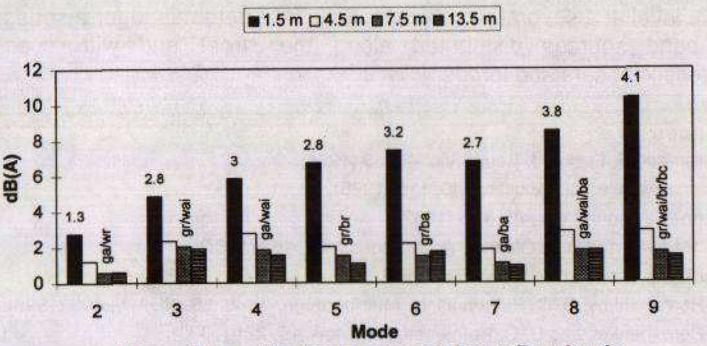

Figure 3. Insertion losses everaged over floor levels.

It can be observed from the graph that the investigated abatement schemes are mostly effective in the vicinity of the ground and that the effect of a combined treatment may not be additive (see Modes 4 and 7 as an example).

Absorbing facades and restraint barriers should be considered as the most effective schemes particularly in combinations (Mode 8). The maximum effect at the pedestrian level was observed when an additional central reservation low profile absorbing barrier was introduced (Mode 9). Note that the low profile barriers (1.1m in height) in absence of any absorbers can provide adequate noise reduction only at the pedestrian levels and are likely to act as unwanted scatterers of acoustic energy towards the higher floors. The finite values of absorption on the barrier's surface do not appear to be critical (compare Mode 5 and 6) unless multiple reflections between the passing vehicles and the barrier need to be controlled.

The absorbing ground did not produce a pronounced reduction in sound levels (Mode 2) and the insertion loss was estimated below 3 dB(A) which is the maximum possible value for non-coherent sources.

5. CONCLUSIONS

A completely new experimental model facility has been developed to study noise propagation in three dimensions from a series of broad band sources. The system has been shown to give good agreement with the results of numerical models for a site layout where all the reflecting surfaces are rigid and when the road surface has finite uniform impedance. Using the experimental model various noise abatement schemes were investigated for a city street environment. The change in overall sound pressure level at a several receiver positions was determined for a series of broad band sources distributed along the street and with spectra characteristic of cars and lorries.

References

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