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FORTY YEARS OF RESEARCH ON TRANSPORT NOISE ABATEMENT: WHAT IS NEW? WHAT REMAINS TO BE DONE?

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ABSTRACT

During the past half century, most acousticians think that improvement of vehicles was insufficient to reduce transport noise in residential areas and that it is very important to be able to predict noise in terms of public reaction and take it in account in city planning

First, approximate calculation methods have been developed for use in simple cases and scale model techniques for more complex situations. Now, computers permit very sophisticated calculations, taking in account wind and temperature gradients, and the prediction is not limited to simply a dB value but permits the real noise to heard with its non measurable qualities.

In spite of these new techniques, scale models remain very useful tools.

1. INTRODUCTION

Many years ago most politicians and town planners believed that problems of traffic noise would be resolved by the development of quiet cars. Forty years ago acousticians said:

" It most important to predict traffic noise and to take it in account in town planning "

Recently we measured noise in Paris at the same points as thirty years ago and, taking in account the traffic variation, we find that the means acoustic power of cars running in streets has not been reduced by more than one dB in spite of the important noise reduction obtained in the test condition which is the European norm.

The same results may be found near highways and the only real progress is in the use of porous asphalt. While the noise emissions have been reduced the braking performance has also been improved. Speed variations are more important in cities and speed is higher on highways. The one solution now is to limit the use of cars in cities and to screen the highways.

French regulation for traffic noise induce very low limits for new roads:

- L_{Aeq} day (6 h, 22 h) < 60 dB(A)
- L_{Aeq} night (22 h, 6 h) < 55 dB(A).

These limits will be adapted to future European regulation and are applicable to the outside, in front of closed windows, at a distance of 2 metres from the façades of houses, when the former noise level did not exceed 65 dB(A).

L_{Aeq} levels may represent annual values. For distance greater than 250 metres meteorological conditions have to be taken in account. Noise levels have to be calculated in the first instance, but may be controlled afterwards by measurements.

The problem of the prediction of noise to agree with corresponding measurements has to be solved.

2. TRAFFIC NOISE PREDICTION

2.1 Taking in account the vehicles

For traffic noise prediction most method take in account vehicles as ideal point sources and traffic flow as ideal linear sources. In future it seems necessary to improve this model which is quite poor for taking in account ground and also for screening calculations. For train noise, C.S.T.B have developed a method taking in account the geometry of a wagon as sound reflection from the body of wagon is very important for screen calculations. The problem is quite similar for trucks.

Some years ago [1], an experimental screen was built in Grenoble with a variable height and a variable surface, either reflecting, or very absorbing.

The length of the screen was limited to 33 m and measuring distance did not exceed 5 m away from the screen. Forty truck passings were measured behind the screen, and also without the screen.

The mean distance between screen and truck body was 3 m. Tables 1 and 2 give the mean insertion loss of the screen for absorbing and reflecting surfaces. The value of α was derived from normal impedance measurements.

For this distance, the insertion loss of the reflecting screen is similar so that obtained by calculations for a source very far away from the screen.

In the 2,000 Hz octave band, some results are affected by aerodynamic noise from the top of the truck (canvas cover).

Table 1

EFFICIENCY OF SCREEN FOR TRUCKS 3m distant

Absorptive screen

HEIGHT of SCREEN	HEIGHT of POINT	OCTAVES 125Hz	250Hz	500Hz	1000Hz	2000Hz
2.0m	**2.0m**	9.0dB	10.0dB	13.0dB	14.0dB	15.0dB
2.0m	**5.0m**	2.0dB	4.0dB	3.0dB	5.0dB	4.0dB
3.5m	**2.0m**	10.0dB	16.0dB	18.0dB	21.0dB	22.0dB
3.5m	**3.5m**	7.0dB	10.5dB	13.0dB	15.0dB	17.0dB
3.5m	**9.5m**	3.0dB	4.0dB	2.5dB	3.0dB	
5.0m	**2.0m**	16.0dB	20.0dB	22.0dB	25.0dB	24.0dB
5.0m	**5.0m**	12.0dB	16.0dB	18.0dB	22.0dB	21.0dB
5.0m	**9.5m**	9.0dB	10.0dB	11.0dB	10.0dB	10.0dB
Normal alpha		**0.5**	**0.8**	**0.9**	**0.95**	**0.95**

Measure at 5m behind the screen

Table 2

EFFICIENCY OF SCREEN FOR TRUCKS 3m distant

Reflective screen

HEIGHT of SCREEN	HEIGHT of POINT	OCTAVES 125Hz	250Hz	500Hz	1000Hz	2000Hz
2.0m	**2.0m**	7.0dB	7.0dB	8.0dB	11.0dB	12.0dB
2.0m	**5.0m**	1.0dB	2.0dB	2.0dB	2.0dB	1.0dB
3.5m	**2.0m**	9.0dB	11.0dB	13.0dB	15.0dB	15.0dB
3.5m	**3.5m**	6.0dB	8.0dB	12.0dB	13.0dB	14.0dB
3.5m	**9.5m**	3.0dB	3.0dB	2.0dB	3.0dB	
5.0m	**2.0m**	14.0dB	16.0dB	18.0dB	20.0dB	20.0dB
5.0m	**5.0m**	10.0dB	12.0dB	15.0dB	14.0dB	17.0dB
5.0m	**9.5m**	5.0dB	6.0dB	7.0dB	8.0dB	10.0dB

Measure at 5m behind the screen

This effect has been measured at a short distance of the screen and may be greater for longer distances.

For ground effect calculations, the height of a source has a very big effect on the result. In reality, tyre noise is emitted on the ground and most acoustic sources are situated under the floor of the vehicle with reflections and scattering between the floor and the road surface. In canyon streets the body of a car will have a scattering effect which may influence sound propagation.

2.2 Taking in account the ground

Sound propagation near the ground is now well know and simple models have been developed for fast geometrical calculation in the case of uniform and plane ground.

In case of a valley it is possible to take in account two ground surface: one near the source the other near the microphone. In case of a random surface the use of a middle plane (ISO) may be a source of important errors. Geometrical methods generally used to take in account ground have to be improved.

For great distance atmospheric turbulence has an important effect on ground propagation.

2.3 Taking in account screens

Simple formulations to predict attenuation by slim noise barriers have permitted the large scale development of their use for the engineering of environmental protection. Simple curves have been published by Redfearn [2] in 1940. Experimental curves have been published by Fehr [3] in 1951 and Maekawa (1965) [4] where the Fresnel number is the parameter. First applied to industrial noise, noise barriers are now mainly used along motorways [5] and railways..

To calculate multiple reflections between two reflective screens, it is very important to take in account the effect of diffraction on the reflected rays.

For the image of the reflected source, the screens have to be considered as a slit.

Diffraction by slit may be written as the inverse problem of diffraction by screen. For example the simple formulation of the screen attenuation D_2 given by ISO 9613-2 becomes:

$$D = -20\log\left(1 - \frac{1}{\sqrt{4+20N}}\right)$$

where:

D is the attenuation in dB of the reflected ray

N is the Fresnel number relative to the path length difference between direct and diffracted rays.

Many researchers have attempted to devise methods of improving screen efficiency [6, 7, 8]. The most usual solution is to put a wide absorbing edge at the top of the screen (cylinder or T).

Industrial products are now developed. A typical improvement is 2 dB for traffic noise for an edge of about 1 m wide. For all of these screen shapes we need of simples geometrical solution to calculate diffraction.

The extension to 3D of the BEM technique helps the calculation of these solutions [9 and 10]. The research into simplified models for determining the diffraction factor will help to qualify these products. Wide edges are especially interesting at oblique incidences. One has to be very careful concerning source modelling when using BEM.

Earth berms with very porous boundary conditions may so, be considered as an improved screen, simple methods for performance calculation have to be developed.

A sloping ground with high absorption very near the road may be efficient for noise protection also in case of wind but its performance is less easy to calculate than that of a simple screen. ISO 9613-2 has not been written to optimise acoustic screening

Roads in cutting with soft earth berms produce a better landscape than acoustics screens.

2.4 Taking in account the climate

C.S.T.B. [11] have developed a method to estimate wind and temperature profile available for noise prediction in France.

Given the meteorological condition, this method employed in the " Mithra " program [12] gives good results. It is useful to correlate prediction and noise measurement. It would be very onerous to use that method for all typical conditions of one typical year for a particular receiver.

ISO 9613-2 gives a general method for calculating the attenuation of sound during propagation outdoors with downwind condition or moderate ground based temperature inversion. The octave band method may be used for traffic noise prediction.

This method has the advantage of being simple. It takes into account a very low ground attenuation in the octave bands 1,000 Hz and above, which have a large weighting for the dB(A) value.

ISO 9613-2 permits only calculations with wind or temperature gradient and uses corrections in other cases. For a better calculation of complicated screening designed for high noise reduction, more efficient methods may be used with ideal atmospheric conditions. Methods with wind conditions will then be applied for control and adjustments.

The long term average equivalent noise level L_{Aeq} is a combination of the two results taking in account the percentage of time meteorological conditions favourable to propagation occur.

C.S.T.B. associated with French Road Laboratories have developed a new method [13] giving a better adaptation of ISO 9613-2 for traffic noise.

For ground effect with wind or temperature gradient, the ISO formulation in octave bands is used.

For screens the meteorological effect with favourable condition is included in the procedure for calculating the Fresnel number by considering for the direct path as a curved path with a curvature of 8 times the horizontal distance between elementary source and receiving points.

The ground effect before diffraction and after diffraction is weighted by the difference of attenuation between direct ray and ground reflected ray.

2.5 Taking in account the forest

Forests produce sound scattering and very absorptive ground. For long distances forests have also a big influence on climatic conditions and limit temperature inversions during clear nights.

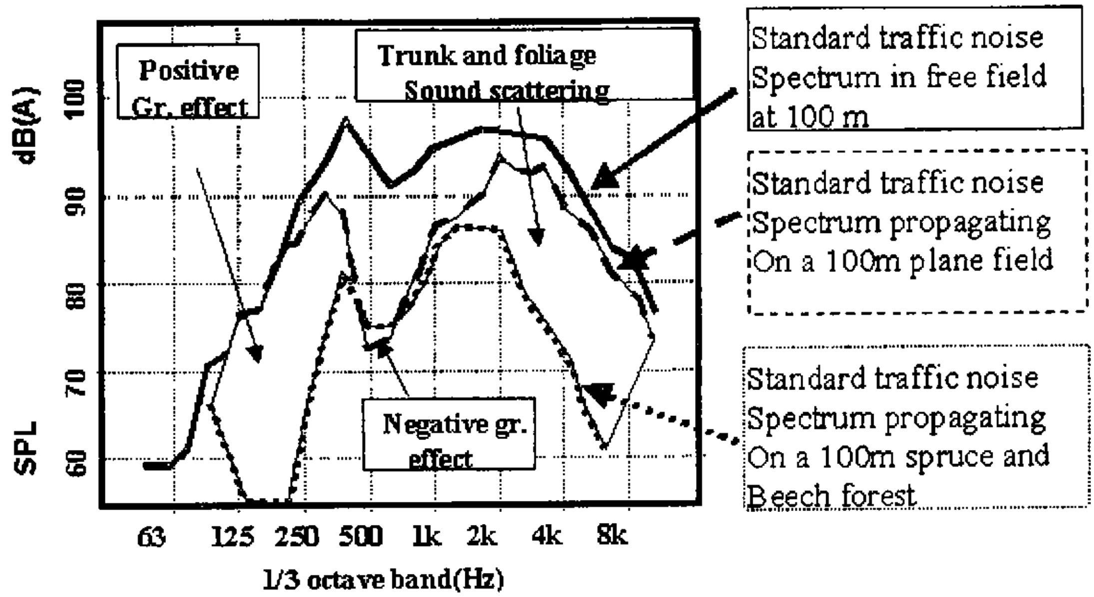

Fig 1 Results of measurements in forest [14] source and microphone 1m height.

2.6 Calculating for virtual reality.

Digitised images are more and more used to present urban projects and sound predictions have to be able to represent digitised sound for three dimensional hearing. Noise sources have to be described without motion and Doppler effects have to be calculate for each point.

2.7 Use of scale models

Scale models have been used for traffic noise prediction and Liverpool University has forty years experience in this technique. Now calculations can replace models in many cases and are able to take in account climate. B E M. is able to take in account architectural details but only approaches three-dimensional calculation. Models remain a method for assessing the effect of architectural details and a method of validating theoretical models.

3. CONCLUSION

Research on environmental noise has made considerable progress but it remains a job for the next century.

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