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COMPARISON OF TWO METHODS FOR PREDICTING TRAFFIC NOISE

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1. INTRODUCTION

The aim of a method for predicting traffic noise is usually the determination of a long term average equivalent continuous A weighted sound pressure level. A long time interval (for example a year) includes a variety of meteorological conditions, either favourable or unfavourable to propagation.

In order to take in account these aspects, a new method has been established in France [1]. This method specifies two calculation procedures : with meteorological conditions favourable to propagation, without meteorological gradient, i.e homogeneous medium. The long terme average equivalent noise level L_{Aeq} is a combination of the two results taking into account the percentage of time meteorological condition favourable to propagation occurs.

This new method has been compared on the one hand with the standard ISO9613-2 [2] which takes into account only the condition favourable to propagation, and on the other hand with experimental results obtained along highways where meteorological data have been collected.

2. A NEW METHOD FOR THE PREDICTION OF TRAFFIC NOISE

Principle

Basically the prediction method is an octave band method. The road is represented by lines of monopole sources. Transmission path attenuation between a point source and the receiver is estimated by mean of additive corrections for spherical divergence, air absorption, ground effect, diffraction, and reflection from vertical surfaces. These attenuations are calculated with two meteorological conditions i.e. favourable to propagation which gives the level L_f, and in an homogeneous medium which gives the level L_h.

The long terme average equivalent noise level L_{LT} is calculated according to the following relation :

$$L_{LT} = 10\log\left(p\,10^{0.1\,L_f} + (1-p)10^{0.1\,L_h}\right) \qquad (1)$$

where p is the percentage of time meteorological condition favourable to propagation occurs in the direction of propagation.
In the present method, the equivalent noise level L_h characterizes the mean noise level without meteorological gradient. Thus, the long terme average equivalent noise level can never be lower than this reference level.

Estimation of the meteorological conditions in situ.

In order to evaluate the percentage of time with meteorological conditions favourable to propagation, a simple qualitative method proposed by Zouboff et al [3] has been used. This method is based on a double entry grid UiTi that only requires simple meteorological observations (Ui a class among 5 classes for the wind speed, Ti a class among 5 classes for the temperature gradient).

Transmission path attenuation

The equivalent sound level with condition favourable to propagation and with homogeneous conditions are calculated with the following relations

$$L_f = L_W - A_f, \quad L_h = L_W - A_h$$

where the transmission path attenuation A_f and A_h between a punctual source and the receiver, in octave bands, are determined according to equations 2 and 3

$$A_f = A_{div} + A_{atm} + A_{sol,f} + A_{dif,f} \qquad (2)$$

$$A_h = A_{div} + A_{atm} + A_{sol,h} + A_{dif,h} \qquad (3)$$

where A_{div} is the attenuation taking into account the effect of divergence, A_{atm} is the air absorption attenuation, $A_{sol,f}$ and $A_{sol,h}$ are the attenuations with ground effect, $A_{dif,f}$ and $A_{dif,h}$ the attenuations with diffraction effect respectively with meteorological conditions favourable and homogeneous.

Ground effect

The transmission path attenuation by ground effect depends upon source and receiver point height, type of ground surface, distance between source and receiver, and whether or not screening occurs along the transmission path. Distinction is made between two types of ground surfaces, i.e hard (asphalt, water ...) and soft (any ground which will support growth). Each of these types have been designated a ground factor G. For mixed surface, G is equal to the fraction of porous ground. The source height (Z_s) and the receiver height (Z_r) are calculated with reference to a middle plane of the profile.
With the meteorological conditions favourable to propagation the ground effect is calculated with the expressions given in the standard ISO 9613-2 with $G_S = 0$ for the source part and $G_R = G$ for the receiver part.

Without meteorological gradient, i.e homogeneous medium, the ground effect is calculated with equation (4)

$$A_{sol,h} = -10\log\left[4\frac{k^2}{d_p^2}\left(Z_s^2 - \sqrt{\frac{2C_f}{k}}Z_s + \frac{C_f}{k}\right)\left(Z_r^2 - \sqrt{\frac{2C_f}{k}}Z_r + \frac{C_f}{k}\right)\right] \qquad (4)$$

where k is the wave number, Z_s the source height, Z_r the receiver height, d_p the distance between source and receiver.

$$C_f = d_p\frac{1+3wd_p e^{-\sqrt{wd_p}}}{1+wd_p}$$

and $w = 0.0185\dfrac{f^{2.5}G^{2.6}}{f^{1.5}G^{2.6} + 1.3\,10^3 f^{0.75}G^{1.3} + 1.16\,10^6}$

This formula is comparable with formula (1) of the paper by J. Defrance, Y. Gabillet [4], where the flow resistivity sigma of the Delany Bazley model is replaced by G according to the relation :

$$G = \left(\frac{sigma}{300\,10^3}\right)^{0.57}$$

$$G = 1 \text{ if sigma} \leq 300\,10^3 \text{ SI}$$

Diffraction effect

The general principle in calculating the attenuation with diffraction is described figure 1.

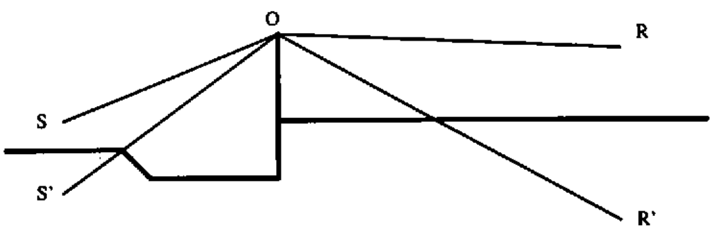

Fig. 1 : Principle in calculating the attenuation with diffraction

The attenuation with diffraction is calculated with the following equations.

- without meteorological gradient, i.e. homogeneous medium

$$A_{dif,h} = \Delta_{dif,h}(S,R) + \Delta_{sol,h}(S,O) + \Delta_{sol,h}(O,R)$$

- with meteorological conditions favourable to propagation

$$A_{dif,f} = \Delta_{dif,f}(S,R) + \Delta_{sol,f}(S,O) + \Delta_{sol,f}(O,R)$$

where $\Delta_{dif,h}(S,R)$ and $\Delta_{dif,f}(S,R)$ are respectively the attenuation with diffraction of the direct path between S and R for homogeneous and favourable conditions of propagation ;

$\Delta sol,h(S,O)$ and $\Delta sol,f(S,O)$ are respectively the ground effect attenuation between the source and the diffraction point for homogeneous and favourable conditions of propagation ;
$\Delta sol,h(O,R)$ and $\Delta sol,f(O,R)$ are respectively the ground effect attenuation between the diffraction point and the receiver for homogeneous and favourable conditions of propagation.
Δdif is calculated using the equation (13) of the standard ISO 9613-2 but with the meteorological coefficient K_w omitted. The meteorological effect with favourable condition is included in the procedure for calculating the Fresnel number by considering for the direct path a curved path with a curvature of 8 times the horizontal distance between S and R [5].

$\Delta_{sol}(S,O)$ and $\Delta_{sol}(O,R)$ are calculated using equation 5 and 6.

$$\Delta_{sol(S,O)} = -20 \times \log\left(1 + \left(10^{-0.05\,A_{sol(S,O)}} - 1\right) \times 10^{-0.05\left(\Delta_{dif(S',R)} - \Delta_{dif(S,R)}\right)}\right) \quad (5)$$

$$\Delta_{sol(O,R)} = -20 \times \log\left(1 + \left(10^{-0.05\,A_{sol(O,R)}} - 1\right) \times 10^{-0.05\left(\Delta_{dif(S,R')} - \Delta_{dif(S,R)}\right)}\right) \quad (6)$$

In these relations the ground effect before the diffraction point $A_{sol(S,O)}$ and after the diffraction point $A_{sol(O,R)}$ are weighted respectively by the difference between attenuation by diffraction for the image-source and the source, and for the receiver and image-receiver in the ground.
This principle is applied to both meteorological conditions favourable to propagation and homogeneous medium. It allows the calculation of the transmission path attenuation either for screens or relief like embankment and wedges [4].

3. COMPARISON WITH MEASUREMENTS

In order to validate this new method, measurement campaigns along highways have been undertaken in different kinds of site. Meteorological data (vertical wind and temperature gradient) were collected every ten minutes at the same time than the mean L_{Aeq} for the different receivers. A classification of the meteorological data with the UiTi grid allows to calculate the percentage of time with meteorological condition favourable to propagation. A first reference receiver is located 30 m away from the edge of the highway, the other receivers are located at different distances up to 550 meters from the source.
The first example is a highway of 2 x 2 lanes with a platform 1.8 m high over a flat ground. Figure 2 shows the attenuation per octave band between a receiver located 300 m away from the edge of the road and 3 m high, and the reference receiver (30 m, 6 m high).

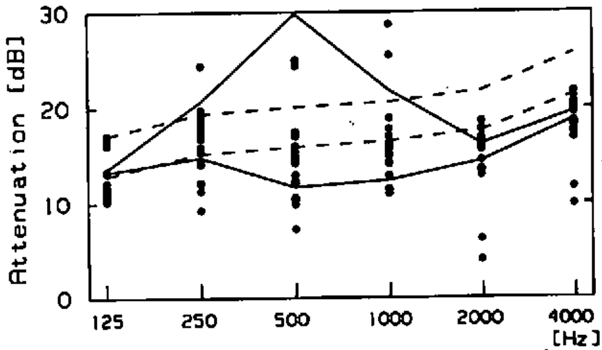

Fig. 2: Sound level attenuation per octave refered to the refence level
- • experimental results (23 results: LAeq (6-22h), LAeq(22_6h))
- — new method with homogeneous (upper curve) and favourable (lower curve) propagation conditions
- - - - method based on ISO9613-2 (lower curve) and with a meteorological correction Cmeteo (upper curve)

These results show that, for this site, the highest experimental level fluctuation occurs in the middle frequency range and these fluctuations decrease in the low and the high frequency range. The new method fits well these tendencies when the meteorological correction effect Cmeteo of the method ISO 9613-2 is constant. For a receiver 550 m away from the edge of the road, the results are quite similar. The experimental attenuations fluctuate between 15 and 27 dB(A), with the new method from 16.8 to 23.7 dB(A), and with the ISO method from 20.7 to 24.9 dB(A). Typical long term attenuation of 16 dB(A) during the night and 21 dB(A) during the day are in a good agreement with the theoretical results.
The second site is quite similar to the first one except that the platform of the road is higher (2.5 m over the mean terrain) and all the receivers are 6 meter high. Three receivers are located 20 m, 120 m, 240 m away from the edge of the road. Results are summarized in table 1.

	Measurement		New method		ISO9613-2	
	min	max	fav.	hom.	fav.	With Cmeteo
120 m/20 m	7	8	7.3	8.3	9.5	12.1
240 m/20 m	11	14	11.6	13.8	14.5	18.1

Table 1 - Leq attenuation in dB(A) for the site nr. 2

The experimental and theoretical (new method) results show that in this example the meteorological effect is weak and the use of a correction term like Cmeteo in the ISO method is not appropriate.
The last example is more complex. It is a highway with a barrier on each side in an urban area. A measurement has been performed in the shadow zone of a earth berm at a distance of 105 m from the axis of the road. A

reference receiver is located on the platform of the road. The experimental and theoretical results are plotted figure 3.

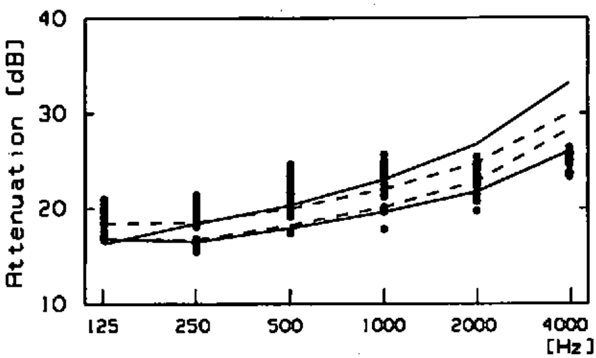

Fig. 3: Sound level attenuation per octave refered to the refence level

Contrary to the first example (fig. 2) , the noise level fluctuations per octave do not exceed 5 dB. This means that the long term noise level will be close to the level calculated in the favourable case. The favourable case for the new method and ISO method are in a good agreement with measurements. On the other hand, the result in the homogeneous case does not fit very well the higher experimental attenuation but the long term attenuation in dB(A) are comparable.

4. CONCLUSIONS

In order to predict the long term equivalent noise level in the vicinity of road infrastructure a new method has been established. Compared to the ISO 9613-2 method applicable with meteorological conditions favourable to propagation, this new method requires in addition the calculation of a reference level without any meteorological gradient. The agreement with long term noise level measurement along highways is good in a lot of situation. Moreover, the summation method gives a better physical description of the noise fluctuations with meteorology than the ISO meteorological correction C_{meteo}.

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