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MOVING NOISE SOURCES
A COMPARISON OF THEORY WITH PRACTICAL MEASUREMENTS

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1. INTRODUCTION

The prediction of the noise level at a distance from a stationary source based on hemispherical spreading is well known and works well in most practical cases over distances less than about 1000 m. The prediction of noise from moving sources has been less well documented. One prediction technique[1] is based on the integration of the point source moving in a straight line at a steady speed. Work carried out by Wimpey Laboratories Limited under contract to the Building Research Establishment involved the measurements of the received Leq due to a number of noise sources moving over short distances and so the opportunity arose to compare the results of these measurements with various theories.

2. THEORY

The Leq in a period T seconds due to a point source moving in a plane can be expressed as:

$$Leq = 10 \log_{10} \left(\frac{\bar{I}}{10^{-12}}\right) \text{dB} \quad \ldots\ldots \quad (1)$$

where $\bar{I}$ is the average intensity received at that point. $\bar{I}$ can be expressed as:

$$\bar{I} = \frac{1}{T} \int_0^T I dt \quad \ldots\ldots \quad (2)$$

where $$I = \frac{W}{2\pi r^2} \quad \ldots\ldots \quad (3)$$

where W = sound power of the source in watts

r = distance from the receiver in metres

both W and r can be functions of t.

If the locus of the point source is known in terms of a set of rectangular co-ordinates x and y centred on the receiver and if the velocity V (which may be a function of t) is known then:

$$(dx^2 + dy^2)^{\frac{1}{2}} = Vdt \quad (4)$$

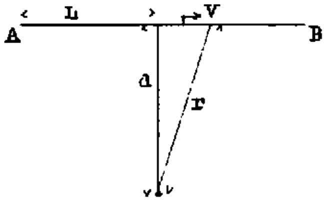
and $$r^2 = x^2 + y^2 \quad (5)$$

if the locus is known then:

$$y = f(x)$$

and dy will be known in terms of dx

We have then, a set of differential equations for the received Leq from a source of any given path at any speed with any given variation in power output. For anything other than the most simple configurations an analytical solution is not possible and numerical methods of varying degrees of complexity must be used to derive solutions. One of the simplest cases is shown below:



A point source moves continually backwards and forwards between points A and B with speed V. Obviously the Leq for this traverse from the centre point to the end point will equal the long term Leq. Let the length of the traverse be 2L. For comparison with the measured results I wish to express the theoretical relationship finally in terms of the distance ratio D where:

$$D = \frac{\text{traverse length}}{\text{distance of closest approach}}$$

$$= \frac{2L}{d}$$

and the equivalent percentage on time P where:

$$P = \frac{\text{Received average intensity}}{\text{Intensity due to source at distance d}} \times 100$$

$$= \frac{\bar{I}}{I_d}$$

where $I_d = \frac{W}{2\pi d^2}$

now, in this case, using equations 2, 3, 4 and 5

equation of locus $y = d$

$$\therefore \frac{dy}{dx} = 0 \qquad \therefore dy = 0$$

$$\therefore dx = Vd.t \qquad \therefore x = Vt$$

$$r = x^2 + y^2 = x^2 + d^2 = v^2t^2 + d^2$$

$$I = \frac{W}{2\pi (v^2t^2 + d^2)}$$

$$\bar{I} = \frac{1}{T}\int_o^T \frac{Wdt}{2\pi (v^2t^2 + d^2)}$$

This is a standard integral

$$\bar{I} = \frac{W}{Vd2\pi T} \left[\tan^{-1} \left(\frac{vt}{d}\right) \right]_o^T$$

integrate to $T = \frac{L}{V}$

$$\bar{I} = \frac{W}{d2\pi L} \tan^{-1} \left(\frac{L}{d}\right)$$

substituting for P, D, and Id

$$P = \frac{200}{D} \tan^{-1} \left(\frac{D}{2}\right)$$

This is plotted in figure 1.

3. MEASUREMENTS

The investigation of moving noise sources involved measurements of the Leq due to mobile construction site plant. Twenty one days were spent on site measuring noise from moving plant, with each individual item being studied for approximately four hours. Where possible, two items of plant were investigated during each visit and on some of the larger sites where there were a number of activities, a second visit was made. In all 22 sets of plant were measured.

On each site visited, the measurement microphone was placed in a position where the major influencing noise source was the mobile plant under consideration. On several of the sites, additional items of mobile and static plant influenced the noise environment at the monitoring position and consequently had to be considered.

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Continuous recordings of the noise prevalent at the monitoring position were obtained over a representative period using a precision tape recorder. The measurement microphone was positioned 1.2 m above ground level with its diaphragm horizontal, and was covered throughout the measurement period by a foam windshield. Analysis of these recordings resulted in traces showing the variations in sound level with time. The equivalent continuous sound levels Leq over the periods of interest were also measured.

Measurements were also made using a calibrated precision sound level meter to obtain the A-weighted sound power level for the moving plant. The maximum A-weighted sound power level of the moving plant was derived from a knowledge of the average maximum A-weighted sound level and the associated distance between the plant and monitoring position. Measurements were made on both sides of the track during several pass-bys of the plant.

A distance ratio, D, was introduced into the assessment of noise from slow moving plant operating over a relatively short traverse, eg loaders. The distance ratio has been defined above. A general relationship was subsequently obtained between the equivalent percentage on time and the distance ratio from the data collected on site and this is shown in figure 1.

For the majority of cases the relationship was found to be accurate to within ± 2 dB(A) although very few measurements were available for distance ratios greater than 6. Therefore for larger ratios the equivalent percentage on time is based on limited information.

Figure 1 compares the measured relationship with the theoretical predicted curve. It can be seen that there is poor agreement. In order to try to improve agreement calculations were performed to derive a relationship for a noise source which stopped at the end of each traverse. In this case the relationship is no longer independent of d and v therefore representative values had to be included. A curve with d = 5 m, v = 10 kph and a stop time of 3 minutes in total at each end of the traverse is shown on figure 1. The curve shows good agreement for higher values of D but the stop time is already rather long. To improve agreement for smaller values of D unrealistically long stop times have to be used. If the source is made to accelerate and decelerate at the start and finish of its traverse this has little effect on the theoretical predictions. Further work on an improved theoretical model to fit the measured data is progressing.

4. CONCLUSIONS

Limited work has been done on the measured Leq due to moving noise sources particularly as applied to construction sites. The practical measurements outlined here indicate that the actual Leq's are quite different from those which simple theory would suggest particularly for short traverses; therefore this would seem to be an area where predicted Leq's need to be based on empirical data.

REFERENCE

1. MARTIN D J and SOLAINI A V. 'Noise of earthmoving at road construction sites'. Transport and Road Research Laboratory Supplementary Report 190UC. Crowthorne, 1976.

Figure 1

Comparison of results with theory