Asimple Estimation Methods for Noise Reduction by Various Shaped Barriers.

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Summary

Simple estimation methods for various noise barriers are reviewed, from the practical point of view of noise control. Some simple charts for the barriers of various bodies are found by experimental and theoretical studies. It has been clear that the integral eqation method is useful to predict the noise reduction by a semi-transparent barrier

Introduction

The acoustic shielding may be achieved not only by a screen but also by many obstacles or barriers such as buildings, earth berms, or terrain that blocks the line of sight from the source to the observer. But the acoustical desing of a barrier is not very easy due to the difficulty in the calculation of sound diffraction around the barrier. In this paper simple estimation methods for various noise barriers are reviewed from the practical point of view. Although the rigorous solutions of sound diffraction are presented by many authors, the simple and pure conditions which are needed for the rigorous solutions can scarecely be found at the practice in citu. Therefor rough estimation methods are still useful in the practice of noise control.

2. Half-infinite Thin Screen for a Point Source

When a half infinite plane screen exist between a point source S and a receiver P in free field, the well known chart of Fig.1 is the sim-

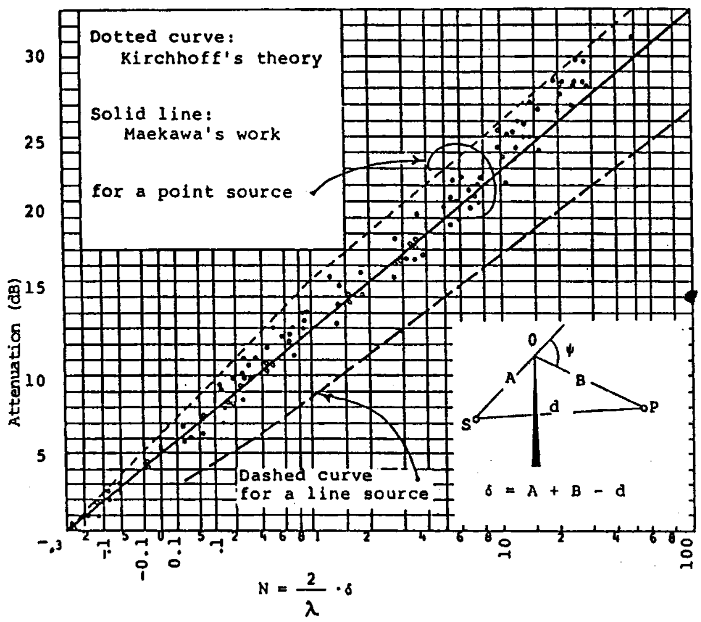

Figura 1

Sound attenuation by a semi-infinite screen in free space. Horizontal scale, logarithmic scale in the region of N>1, adjusted so that the experimental curve becomes a straight solid line in the region of N<1. Depending on whether N<O or N>O, the receiving point P lies in the illuminated region or in the geometrical shadow, respectively. Attenuation is relative to propagation in free space. o; experimental values measured by pulsed tone.
($\psi \leq 90^o$)

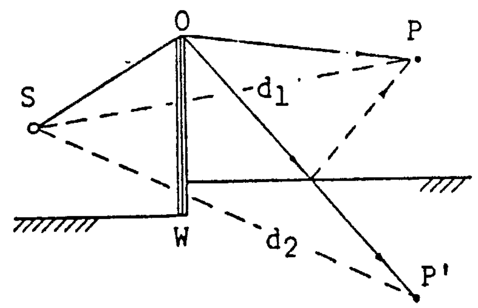

Figura. 2 Section of the long wall betw en a sound source S and a receiving point P.

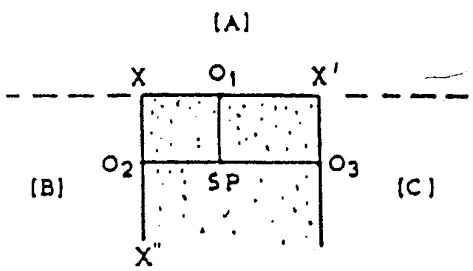

Figura. 3 Limited semi-infinite screen.

plest and reliable method to get noise attenuation with reasonable accuracy, though the results generally have values lower by a few dB than those Kirchhoff's approximate theory as shown in the figure. 1) In the region of N 1, the attenuation is expressed by

$$[Att]\ 1/2 = 10 \log (20N) \qquad (dB)\ (1)$$

It is proved that this expression is the first term of an asymptotic formula derived from the exact theory of diffraction by Keller. 2) For the entire range of N, Formula (2)

$$[Att]\ 1/2 = 5 + 20 \log \qquad (dB)\ (2)$$

is convenient for calculation by aid of a computer, though it has a small discrepancy, within 1 , 5dB only in the range N<1. 3)

The variable N is calculated with the value of δ, the path length difference which may be simply obtained by geometry.

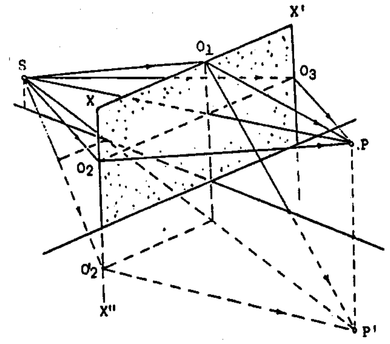

Fig. 4. Propagation paths around the finite size screen.

3. Simple Estimation of the Effect of Ground Reflection

When the long screen WO is erected on the ground between S and P, and distances between them are not long as shown in Fig. 2, the sound pressure level at P can be predicted according to the following process: 1)

(1) The sound level L_0 at the top of the screen is asigned the reference value of the sound level at any point in the shadow zone of the screen. By this procedure both the directivity of the noise source and the reflection from the ground between S and the screen can be approximately neglected.

(2) The effect of ground reflection is calculated by the summation of the sound energy received at P and P', the image of reciever P, assuming perfect specular reflection on the ground

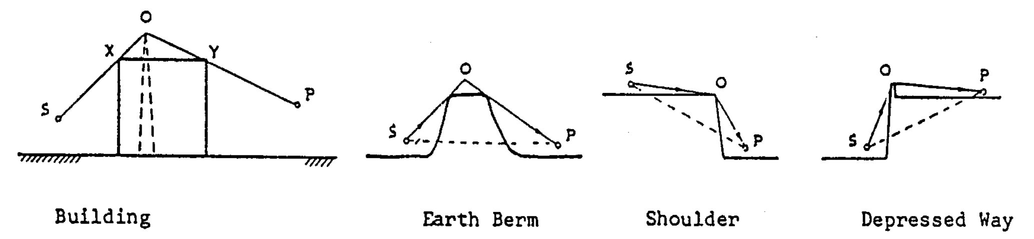

Figura. 5 Noise reduction can be obtained by Fig. l by using the path difference of each case.

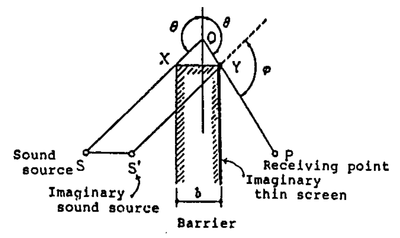

Figura. 6 Geometry of a thick barrier and a imaginary thin screen.

and neglecting their phases. If the summation is expressed by L_3 in the level of attenuation, the sound level at P with the screen is obtained by

$$L = (L_0 - 20 \log \qquad) - L_3 \qquad (dB) \ (3)$$

(3) The shielding effect of the screen, however, must be obtained by the expression (L_p - L) dB, where L is the value calculated by the method mentioned above and L_p is the measured value of the sound level at the point P when the wall is absent. We call it the insertion loss of the screen, and it is variable owing to both the directivity of the sound source and the reflectivity of the ground.

4. Attenuation by a Finite-size Screen

In general, even if a wall or screen has any shape, the sound level in the shadow zone of the screen must be integrated all contributions from the open surface.

In the simple case where the length of the semi-infinite screen in free space is limited on both sides, as shown in Fig. 3, the open surface should be divided into three zones (A), (B) and (C).

Zone (A) is then a half-infinite empty plane, and both (B) and (C) are quarter-infinite zones.

The contribution of a half-infinite open surface, of course, can be obtained by the chart of Fog.1. The contribution of quarter-infinite open surface can be obtained by the sum of the two attenuation values of semi-infinite screens, according to the Fresnel-Kirchhoff's diffraction theory. 1) These values, of course, are easily

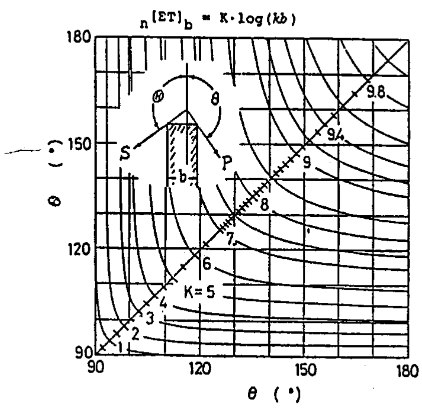

Figura. 7 The values of K in Eqn. (5) to calculate the effect of thickness of a noise barrier.

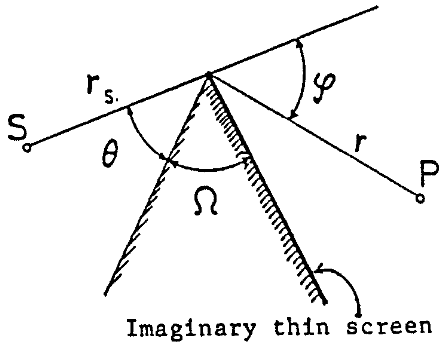

Figura. 8 Notations of the wedge diffraction.

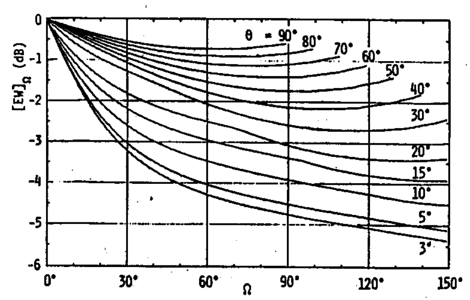

Figura. 9 Effect of wedge-angle Ω with a parameter of source angle β.

obtained by the chart of Fig.1, and added together with its energy neglecting their phaces.

In the same way as shown in Fig.2, the sound wave reflected from the ground is calculated at the point P′, the image of P as shown in Fig.4, considering the specular reflection of the ground. The sound energy at the receiving point P and that at the image P′ should then be added together.

When a thin screen has a complex multilateral shape, the sound level in the shadow zone of it can be obtained by the same principle mentioned above as you can find in the literature. 4)

5. Simple Estimation for Barriers of Various Bodies

Until now, the screen is assumed has zero thickness. The barriers, however, have their own bodies as shown in Fig.5. As a first approximation to calculate noise reduction, by using the chart of Fig.1 with the value of the path difference, $\delta = \delta O + OP - \delta P$ or $\delta = \delta X + XY + YP - SP$. This is the simplest way though there are more accurate methods as follow:

(A) Effect of the Thickness of a Screen. 5)

According to many experimental data, the effect of the thickness of a screen should be negligible as long as the thickness is smaller than the wave length. A thick plate or wide barrier has two edges which increase the noise reduction by double diffractions.

The attenuation of a band noise by a thick barrier $_n[Att]_b$ is assumed to be composed of the attenuation by a imaginary thin screen $_n[Att]_o$ and the effect of the thickness of the barrier $_n[ET]_b$ expressed by

$$_n[Att]_b = {}_n[Att]_o + {}_n[ET]_b \quad \text{(dB)} \quad (4)$$

Fig. 6 shows the geometry of a thick barrier and a imaginary thin screen. S and P are the sound source and the receiving point, respec-

tively. SO is parallel to S´Y and SS´ is parallel to XY.

$_n[Att]_O$ is the attenuation of sound by the imaginary thin screen from S´ to P passing Y.

After theoretical research, though the results of the computation of the exact solution show the resonance effect related to the thicknees, b, with reasonable approximation, the effect of thicknees for a noise having a considerable band-width is obtained from

$$_n[ET]_b = K. \log (\kappa \tau) \quad \text{(dB) (5)}$$

where K is the value given by the single chart of Fig.7, and

$$k= \quad (6)$$

(B) Effect of the Angle of a Wedge. 6)

Many barriers of various bodies, have wedges at their corners wich cause sound diffractions. The theory of the diffraction by a wedge has been treated by many authors. Now, from the practical point of view, the effect of the wedge-angle Ω, which must be added to the attenuation by a imaginary thin screen, in a way similar to that of a thick barrier, is derived from the exact theory, as follows:

$$[Att]_\Omega = [Att]_O + [EW]_\Omega \quad \text{(dB) (7)}$$

where,$[Att]_\Omega$ is the noise attenuation by the wedge wich has wedgeangle Ω, and$[Att]_O$ is the nise reduction obtained from the chart of

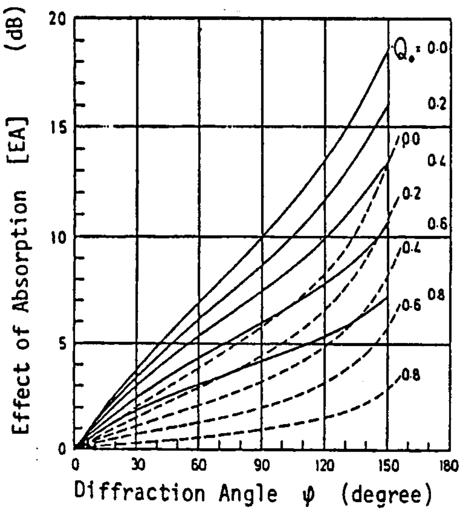

Fig. 10 Effect of surface absorption of a barrier calculated for a thin half infinite plane. Dotted curve; for a point source, solid curve; for a line source. Q_O; sound pressure reflection coefficient.

Fig.1 by the imaginary thin screen, as shown in Fig.8. From many results of the numerical calculations of the exact solution, we obtained a single chart of $[EW]_\Omega$ as shown in Fig.9 with some approximations. $[EW]_\Omega$ is a function not only of the wedge-angle and the source angle γ θ but also the diffraction angle xxx, with the notations as shown in Fog.8. But the effect of γ can be negletected, and the values of the curves show the negative largest values, in order to be on the safe side for the practical noise control. It is clear that $[EW]_\Omega$ decreases the barrier-attenuation from that of the thin screen, but not over -6dB, and vanishes when

Ω O.

Both methods for obtaining the effects of thickness and wedgeangle are certified for their usefulness by many experiments.

6. Effect of Surface Absorption of the Barrier

All barriers discussed above are assumed have rigid surface. But, the barriers treated by sound absorbing materials are widely used. The effect of surface absorption of a half infinite screen is given by using exact theory of diffraction. The result of theoretical consideration under some simplified condition is shown in Fig.10. 7) The effect of surface absorption is a function of the diffraction angle xxx, and the values are calculated in the far field for various reflection coefficients of the screen surface.

We can estimate the effect quickly by only adding the value of Fig.10 to the value of attenuation by the reflective barrier.

7. Large Extended Noise Source

It is a more difficult problem to obtain a theoretical solution of sound diffraction with a large source, because the wave front from the large source cannot be expressed exactly. There is conventional method, however, if the large source can be replaced by one or more point sources. When the noises are emitted incoherently from virtual point sources, the sound energy received from each point source, which can be obtained as mentioned above, should be added together at the receiving point.

So that the shielding effect of the barrier for the group of sources can be expressed as follows, 8)

[Att] = 10 log { Σ

(dB) (7)

where K_i: the factor for the power of each point source, Ω : the distance from each source to the receiver, and $[Att]_i$: the value of attenuation due to the barrier at the receiving point for each source, which can be obtained as described above.

For a special case of a street or a highway, noise emission is often treated as an incoherent line source. The performance of a barrier against highway noise should be considered with a line source parallel to the edge of the barrier. The results of the theoretical computations and also experimental studies are shown by a dashed-curve in the chart of Fig.1.

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