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"SOUND RADIATION FROM BUILDINGS"

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Introduction

In recent years many new building projects have been granted planning permission on condition that the noise level arising from their use does not exceed a certain value measured at the site boundary. The problem facing the designer in meeting these conditions is that there is at present no reliable method of predicting the noise levels radiated from a building from a knowledge of its construction, orientation or the sound power generated by internal sources.

A complete building is a very complex unit and one approach is to assume that the major proportion of sound radiated from it escapes via such acoustically weak elements as doors and windows. Parkin and Humphreys (1) give the following expression for the noise level at a distance metres from an acoustically weak partition set into a massive wall.

$$L_2 = L_1 - R + 10\log S - 20\log r - 14 \quad dB \quad (1)$$

where L_1 is the average level inside the building, L_2 is the level at a distance r metres from the partition and along the normal to the partition, R is the sound reduction index of the partition and S is its area.

Parkin and Humphreys state that once one moves away from the normal it is impossible to calculate the external noise level.

In this paper the results of some preliminary studies of sound radiation from buildings using the techniques of acoustic scale modelling and computer simulation are reported. These studies were restricted to the action of an acoustically weak element in a wall. The initial approach was to examine the radiation pattern from an aperture and then to investigate how this was modified following the blocking of this aperture with a material of lower sound reduction index than the rest of the structure.

Radiation from an aperture

A computer model was developed to predict the radiation pattern of sound from a large aperture. Equation 1 is derived from classical reverberant field theory hence it was decided to approach the problem from this point of view.

The classical ray approach starts with the assumption of a uniform diffuse sound field in an enclosure. A volume element is established in this field and is treated as a pseudo-point source. In order to calculate the energy per unit area per unit time arriving at a point on the walls of the enclosure the volume element is extended to become first an elemental ring and then a hemi-spherical shell (Fig. 1). For this situation an analytical solution is possible.

A variation on this theme was used to calculate the radiation pattern of sound from an aperture in one of the walls of an enclosure. A number of small volume elements, each a distance r metres from the exterior receiving point, were established in the reverberant space (Fig. 2). For elements in the "bright" and "transition" zones (in direct line of sight to the receiving point) these were merely situated on an arc of radius r centred at the receiving point. In the "shadow" zones the elements were on an arc of radius r minus the distance from the diffracting edge to the receiving point centred on the diffracting edge. Although figure 2 shows a two-dimensional representation of the model this is merely for clarity and the three-dimensional nature of the situation was fully considered in the computer model.

To calculate the level at the receiving point each volume element was treated as an omni-directional point source. The intensity due to an element in the bright zone was calculated using the inverse square law as

$$\Delta I = \Delta V \mathcal{E}_0 c / 4\pi r^2 d \qquad (2)$$

where ΔI is the intensity at a distance r metres from the volume element, ΔV, d is the thickness of this element, c is the velocity of sound and $\mathcal{E}_0$ is the energy density of sound in the enclosure.

The intensity at the receiving point due to elements in the "transition" and "shadow" zones is affected by diffraction at the aperture boundaries. The rigorous theoretical treatment of the diffraction of a reverberant sound field by a large aperture is very complex. A much simpler approach was used in this work. The assumption was made that, provided the elemental volumes were not positioned too far into the room (< 0.5m), most of them would "see" a simple linear barrier. Diffraction by such a barrier has been the subject of considerable research (2) and many formulae are available for predicting their effect on sound from a point source. One such formula, due to Delany (3) was used in this work.

The intensity of sound at the receiving point due to an element in a "transition" or "shadow" zone is given by

$$\Delta I = \Delta V \mathcal{E}_0 c . att. / 4\pi r^2 d \qquad (3)$$

where att = the attenuation factor calculated using Delany's equation.

The total intensity at the receiving point is thus given by

$$I = \left[\mathcal{E}_0 c / 4\pi r^2 \right] \times \left[\sum_{i=1}^{I} \Delta V_i + \sum_{j=1}^{J} \Delta V_j . att_j + \sum_{k=1}^{K} \Delta V_k . att_k \right] \qquad (4)$$

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where the subscripts i, j and k refer to elements in the "bright", "transition" and "shadow" zones respectively and the total number of elements in each of these zones is I, J and K.

Comparisons were made between the predictions of the computer model and measurements made on an 1:10 scale model. The agreement between the two sets of data was found to be good. Figure 3 shows a typical set of results.

The computer model was then used to examine the effect of systematically varying the aperture size, distance of the receiver from the aperture and frequency of sound. From this study the following general conclusions were drawn:-

a) For practical sizes of aperture the most significant factors in determining the radiation pattern are width of aperture and frequency of sound (Fig. 4).

b) For all practical purposes the radiation pattern from a given aperture at a given frequency in the far field is independant of the distance to the receiver (Fig. 5).

Radiation from a Window

The next step was to examine the effect of closing the aperture with a material of low sound reduction index. This approximates to the situation encountered in practice with a glazed window hence in the following discussion the terms window and glazing will be employed to describe the closed aperture and material employed respectively.

The transmission loss of a limp panel is given by

$$TL_\theta = 10 \log\left[1 + (\omega M \cos\theta / 2\rho_o c)^2\right] \text{ dB} \quad (5)$$

where θ = angle to normal, ω = angular frequency of sound, M = superficial mass of panel and $\rho_o c$ = characteristic impedance of air.

From equation 5 it is apparent that the material used to glaze a window will have directional properties. The first approach used in this work was to investigate whether the directional properties of the aperture and glazing material could be combined in a simple manner.

The amount by which the transmission loss at a given angle and frequency to the normal decreased relative to the transmission loss at the normal was subtracted from the attenuation relative to the normal observed for an aperture at the same angle and frequency. A comparison of the radiation pattern predicted in this way with experimental measurements is shown in Figure 6. It can be seen that this simple technique does not predict the radiation pattern when the aperture is glazed. The effect of the glazing is quite pronounced and tends to make the radiation pattern from the aperture more hemi-spherical than in its absence.

Conclusion

The simple technique described in this paper can be used to predict the radiation pattern of sound from a large aperture in an enclosure containing a reverberant sound field. The technique breaks down, however, once the aperture is glazed. Adoption of a new technique, perhaps based upon the method of de Vries and Hofschreuder (4), is necessary for this situation.

References

(1) P.H. PARKIN and H.R. HUMPHREYS 1969 p. 273 "Acoustics, Noise and Buildings", (Faber).

(2) U.J. KURZE 1974 J. Acoust. Soc. Am. 55, 504-518 "Noise Reduction by Barriers".

(3) M.E. DELANY 1972 N.P.L. Acoustics Report Ac 57 "A Practical Scheme for Predicting Noise Levels Arising from Road Traffic".

(4) D. de VRIES and E. HOFSCHREUDER 1977 Acoustics Letters 1, 117-123 "Directivity Effects in the Far Free Field of a Vibrating Rectangular Wall".

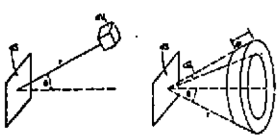

fig 1

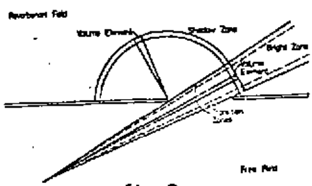

fig 2

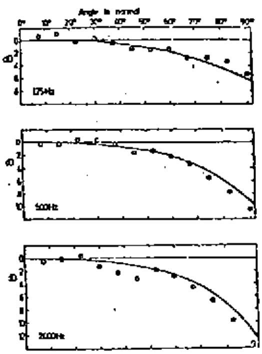

fig 3

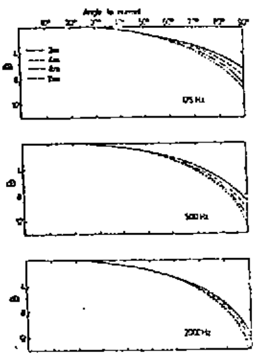

fig 4

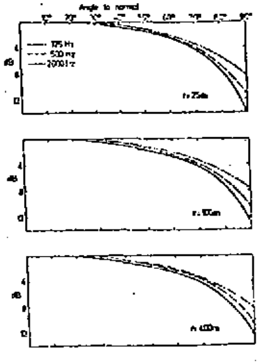

fig 5

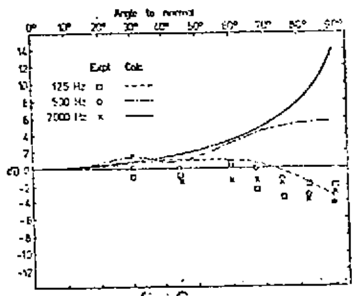

fig 6