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THE ACOUSTIC PROTECTION OF PERFORATED SCREENS FOR BUILDINGS IN HOT CLIMATES.

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INTRODUCTION

The facades of buildings in hot climates should be such that solar penetration is reduced to an acceptable level, there is sufficient ventilation to ensure thermal comfort, daylighting is plentiful without the introduction of glare and the internal background noise level is such as to provide a pleasant aural environment. One design solution involves the use of a sealed skin plus mechanical ventilation or air conditioning. In seeking a design solution where the facade is perforated and thus allows natural ventilation the architect would normally assume that there would be little acoustic protection from external noise such as that due to road traffic. This is unfortunate since in less well planned city developments effective traffic noise control will, for the time being, result only from the use of acoustically self-protecting facades.

In this paper a description is given of an investigation, involving computer modelling, scale modelling and field measurements, into the acoustic protection of perforated screens which, by virtue of geometry, diffract the sound away from the line of propagation [1,2,3]. The screen geometry is that proposed by Wirt [4] for free standing barriers in which a saw-tooth shape can be viewed as a screen the transparency of which increases with increased height. In the right conditions an amplitude gradient device results (termed a Thnadner by Wirt) and the sound field is redirected away from the receiver position.

THEORY

A brief description of the amplitude gradient device is best given in terms Fresnel theory given in [4] and many other tests. Thus in figure 1 the contribution at a receiver point of a cylindrical wave front is given as a vector sum OZ of the contributions from sub-zones which differ from each other

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by a constant phase angle (in this case 20°). The resultant Cornu spiral is shown only to one half the wave front. If the wave front is further blocked, in this case upto the first half-period zone, then a shortened vector summation BZ results.

If the vector components are selectively reduced by means of a barrier with transparency which increases with increased barrier height as indicated in Figure 2 then the resultant vector might be made to begin and end at Z and have zero magnitude. Such a condition is likely to be attainable only with particular combinations of source-barrier-receiver geometry and sound wavelength but results of computer simulation and scale model measurement have been promising for a wide range of conditions.

SCALE MODEL MEASUREMENTS

Figure 3 shows a scale model (of scale factor 1:10) of one of the saw-tooth profiles investigated. The experimental investigation was conducted in the anechoic chamber of Liverpool University. Sound levels were recorded at points on a 100m grid at a distance from a line array of twelve piezo-electric tweeters each of which was supplied by a separate white noise source and amplifier. The sources were thus phase independant although of equal magnitude. Measurements of one third octave sound level over the grid area were obtained with and without the barrier in position. A solid barrier of same height was used for comparison. Figure 4 shows the measured and predicted protection of a thnadner relative to that of a solid barrier of same height for a scale source distance of 1m and a receiver height of 100mm and 200mm. In general it was found that the measured protection of the saw-tooth barrier was greater than would be obtained from a regularly perforated barrier of the same percentage perforation which did not offer an amplitude gradient. It is seen that at low receiver heights and in the mid frequency range results compare well with those of a solid barrier. At low frequencies the ratio of wavelength to barrier dimension is high and the wavefront is not selectively perturbed; at high frequencies the ratio is low and the sound will tend to 'beam' through openings without producing interference.

It is possible to give a general description of the acoustic shadow zone behind a free saw-tooth barrier. Where the line of sight is blocked by the solid base of the barrier the protection relative to that of a solid thin barrier of equal height varies between -1 dB and +8 dB. The second zone extends to a line produced from the source and intersecting the barrier at half-height; here the relative protection varies between -4 dB and -2 dB. In the third zone above the situation is worse than if no barrier was present.

From the description the interesting possibility arises of using these screening devices as an integral part of a facade which is otherwise acoustically weak. It will be appreciated that the mechanism of protection is that of sound redirection rather than absorption of reflection and it may be necessary to introduce carefully placed absorbant in order to prevent the redirected sound being subsequently reflected towards the noise sensitive rooms.

A scale model building facade was constructed in the anechoic chamber. Again the measured acoustic protection of a screen is obtained from the difference in room average level before and after inserting the screen; the protection was expressed as a function of frequency, an A-weighted value or a sound insulation index rating. The screened facade elements were a courtyard and closed balcony and solid and conventionally perforated screens were also included for comparison. A courtyard element in this context is defined as a walled area without roofing. Balcony depth and floor level could be varied and all results are in the term of full scale equivalent dimensions and frequencies.

RESULTS

In Figure 5 is shown the effect of courtyard depth and floor level on the A-weighted protection of a courtyard element containing a saw-tooth screen. At ground floor level the protection increases by approximately 3 dBA for one metre increment in courtyard depth levelling off above ground level at approximately 24 dBA. The best position of courtyards with such screens from an acoustical consideration is seen to be above ground level and for depths of 2 metres or more.

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In Figure 6 is shown the effect of introducing a saw-tooth screen to an open fronted balcony at fifth floor level. The increase in protection is appreciable and compares well with the performance of a courtyard with a solid wall.

The results were assessed in the context of the performance of a conventionally perforated screen and it was found that the saw-tooth acoustic protection is much greater for the same or greater percentage perforation (typically 35%).

CONCLUSION

The measured acoustic protection afforded by saw-tooth profiles was appreciably greater than that of a perforated screen which does not offer an amplitude or phase gradient. This is true for the case of a free standing barrier or as part of a building facade.

The screens give good protection only in conjunction with carefully placed ceiling absorbant. Ideally they are best employed as part of a courtyard element where the redirected sound is not subsequently reflected into the protected room.

It is fortunate that these devices give in general a maximum improved protection at the lower floor levels and for floor depths of 2 metres since it is for this case that the requirement for acoustic protection is often greatest.

It was noted during this investigation how relatively insensitive the performance parameters were to the geometry at these devices. Provided an amplitude gradient was produced then increased acoustic protection was obtained. Thus, in the case of a thnadner screen, any saw-tooth configuration, no matter how crudely constructed, should give greater protection than could be expected from conventional theory on perforated barriers.

It remains to investigate the acoustic protection of thnadner screens as components of real balcony or courtyard elements and field measurements are at present being conducted in Liverpool.

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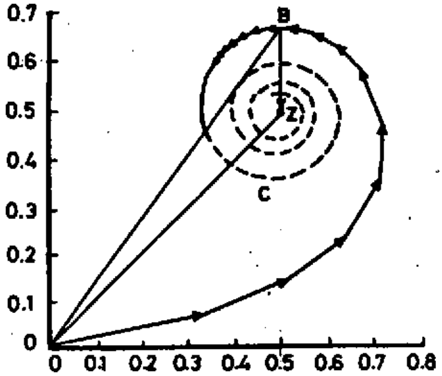

Figure 1 Vector diagram for a cylindrical wave field

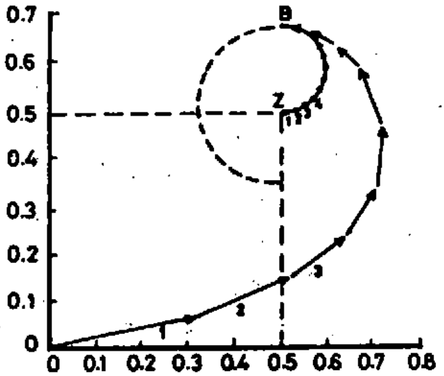

Figure 2 Example of the use of graduated attenuation of the first nine sub zone vectors to generate a perfect shadow

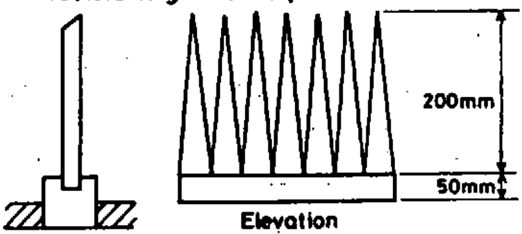

Figure 3 Model saw-tooth profile

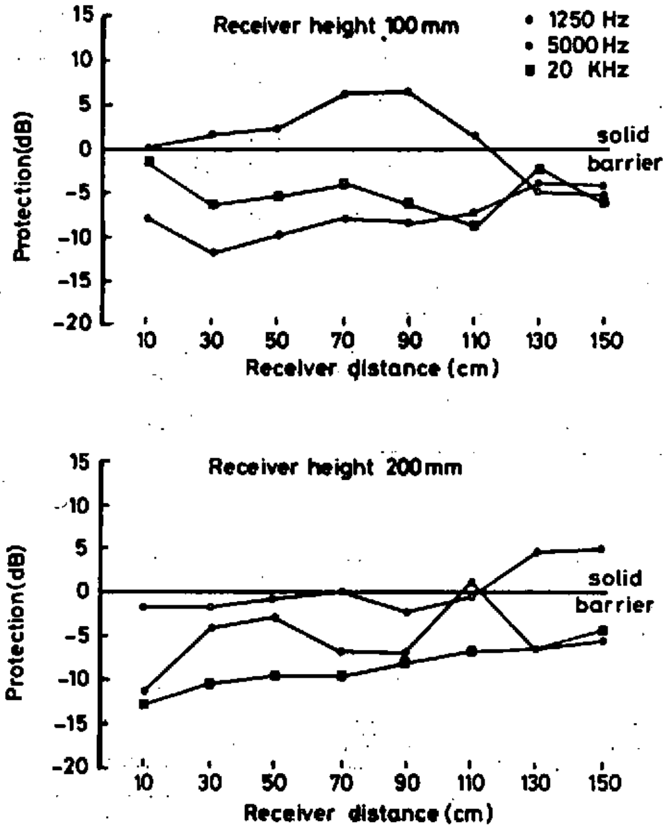

Figure 4 Saw-tooth barrier protection compared to that of a solid barrier

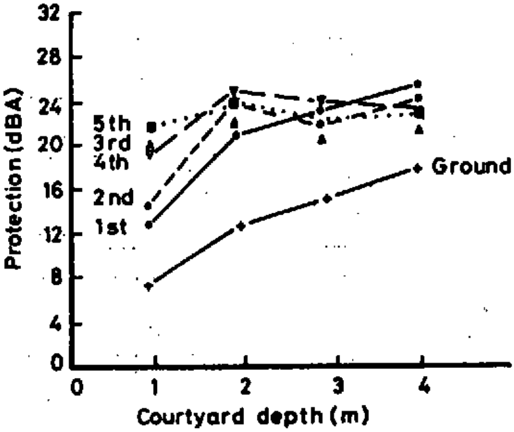

Figure 5 Courtyard protection with a saw-tooth screen

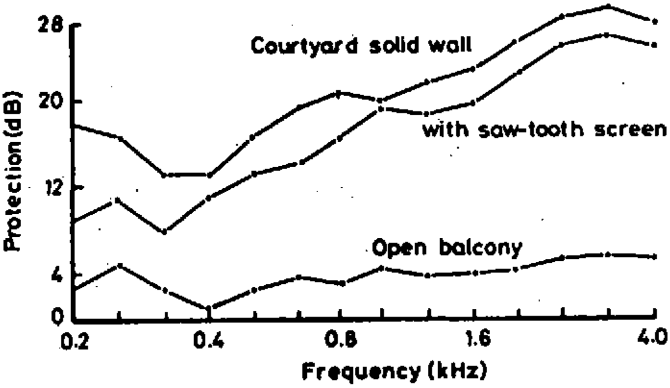

Figure 6 Protection of balcony with saw-tooth screen