Proceedings of The Institute of Acoustics

THE USE OF THNADNERS FOR THE CONTROL OF NOISE FROM ROAD TRAFFIC

S Naceri, P.B. Awosika and D.J. Oldham

Department of Building Science, University of Sheffield,
SHEFFIELD. S10 2TN

INTRODUCTION

The use of barriers to reduce levels of traffic noise is now well established. Manuals for barrier design usually state that the barriers should be imperforate and that the presence of any perforations will seriously degrade their performance. However, in 1979 Wirt [1] suggested that barriers with particular patterns of perforations could in fact produce a greater attenuation of noise than a solid barrier of equal height. He suggested in particular that if the perforations caused the barrier to have a "transparency gradient", considerable acoustic benefits could result. A transparency gradient can be achieved by giving the elevation of the barrier a saw tooth pattern. Wirt gave the name thnadner to this type of barrier after a mythical creature described in the following poem [2].

> "And Thnad is for Thnadners
> and oh, are they sad, oh!
> The big one you see, has the smaller one's shadow.
> The shadow the small Thnadner has should be his.
> I don't understand it, but that's how it is.
> A terrible mix-up in shadows! - Gee Whizz."

Wirt [1], developed the original theory based upon simple Fresnel diffraction theory assuming a coherent line source. He proposed that the attenuation of a thnadner be expressed relative to that of a solid barrier of equal height. He argued that if the attenuation was calculated for both a solid barrier and a thnadner of equal height based upon the incorrect assumption of a coherent line source, any resultant error might be expected to be similar in both cases. Thus by calculating the relative attenuation of the thnadner with reference to a solid barrier, this quantity could then be added to the attenuation of a solid barrier predicted using a validated theoretical or an empirical model.

One consequence of this theoretical approach, however, is that the pitch of the thnadner (assuming a saw tooth configuration] is not considered to be important.

Wirt measured the performance of some thnadner configurations employing a one sixth scale model. The results drawn from his investigation indicated that a thnadner can give acoustic protection ranging between +3dB to -3dB relative to that of a solid barrier of equal height.

May et al [3], also confirmed the effectiveness of thnadners at frequencies below 500 Hz and at receiver distances less than 5 metres from the barriers. Hutchins et al [4], carried out work on similar barrier shapes to May and Osman and they observed an important improvement of a few dB for thnadners compared with plain barriers. However, both works did not discuss the effect of the size of the pitch on thnadner performance.

Maekawa [5], presented a new theory for predicting thnadner performance and performed scale model tests on various shaped noise screens including thnadners. The conclusion drawn was that if the pitch is smaller than half the wavelength of sound, the sound level distribution behind the thnadner will be uniform in the direction parallel to the thnadner.

Gibbs and Hammad [5], investigated the performance of simple thnadners and also self-protecting buildings incorporating thnadners as screening elements. They reported that although thnadners could give attenuation comparable to solid barriers for a receiver in the shadow zone they redirected sound into the bright zone.

It can be deduced from the previous discussion that more work needs to be done on thnadners in order to predict their performance as linear barriers alongside roadways. Another possible use of thnadners is as the screening elements in self-protecting buildings where their open nature may have beneficial effects with regard to ventilation. The objectives of the preliminary study described in this work were thus:

(1) To assess and measure the acoustical performance of thnadners with different sizes of pitch in order to identify the most suitable size for the control of traffic noise.

(2) To measure to what extent a self-protecting building incorporating a thnadner as the screening element can reduce traffic noise.

THE SCALE MODEL EXPERIMENT

Four types of noise screen were initially investigated using 1/10 scale models. Three of the screens were thnadners which had saw toothed indentations as shown in Figure 1. The spaces between the teeth (pitch) were 0.20m, 0.10m and 0.05m respectively corresponding to 2m, 1m and 0.5m in real life situations. The fourth barrier was a solid wall intended to be a reference screen and had the same thickness of 0.012m.

The sound levels were recorded by means of two microphones, (B&K type 4165). One was placed above the top of the screen to act as a reference microphone and the other was positioned at the desired receiver positions.

Many investigations have treated traffic noise as a line source. However, in this work it was decided to look at the problem in terms of a point source (i.e. single vehicle) since, if the performance can be predicted for the sound emitted by one single vehicle, the effect of a stream of vehicles can be mathematically predicted. This enables the attenuation in terms of parameters such as the L_{10} level to be determined. Use of a line source means that the performance of the screen can only be expressed in terms of L_{eq} attenuation.

For this work, the desirable characteristics of the prototype source for the model include:

(1) Broad band output
(2) Almost omni-directional radiation characteristics
(3) Appropriate spectrum (ie. similar to that of 'A' weighted traffic noise at the model scale).

The source employed was an air jet similar to that originally developed by Delany et al [6]. This fulfilled the first two criteria but did not have the correct spectral characteristics. However, the spectrum was measured using a B&K Type 2131 Digital Frequency Analyser and could be mathematically corrected to yield an 'A' weighted traffic noise spectrum.

EXPERIMENTAL RESULTS

The Linear Barrier

A number of experiments were carried out to measure the attenuation afforded by the thnadners. Figure 2 shows results obtained from the three types of thnadner initially investigated. The thnadners were denoted types 1, 2 and 3 where the pitches were 0.2m, 0.1m and 0.05m respectively. In general, the attenuation obtained with thnadner [3] is higher than that obtained with the other models.

The results obtained from both computer and measurements were converted to dB(A) assuming a traffic noise spectrum (see Figure 3). The measured values and predicted values of dBA attenuation of thnadner screens were compared. It was apparent from this comparison that the agreement between measured and predicted data was fair for thnadners two and three, where the coefficients of correlation were 0.95 and 0.96 respectively. However, for thnadner one (0.2m pitch) the coefficient of correlation was 0.76 and the agreement was poor.

The attenuation provided by a thnadner for traffic noise is thus greater when the pitch is small. Therefore, for a thnadner to be effective it is suggested that the pitch should be less than half the wavelength of the dominant frequency of the noise source. A thnadner screen of pitch less than 0.3m should be selected for application to self-protecting forms where traffic is the dominant noise source.

Thnadners as Screening Elements for Self-protecting Buildings

Self-protecting buildings are buildings in which an element acts to shield an acoustic weak point such as a window. It has been shown that self-protecting buildings in which the screening element is a solid wall can reduce noise levels experienced in protected internal spaces [7] Gibbs and Hammad have shown that the use of thnadners as screening elements can also give good acoustic protection [5, 8].

In this section, the acoustic environment of a protected indoor space (i.e. room) is studied for two types of courtyard and balcony acting as a screening agent (thin wall and thnadner screens) and the results obtained are examined with respect to their effect on traffic noise.

Courtyard Houses

Two types of barrier were constructed, a thnadner (0.025 pitch) and a solid wall. All models were constructed from chipboard of thickness 0.012m. The performance of thnadner and the solid walled balconies was examined, with a room dimension of 3m in width, 4m length and 2.8m height, and the size of the window was 1.5 by 1.3m. It was judged that the best representation of the acoustic environment inside the room was the average sound pressure level.

The road was fixed to be 7.5m from the centre line of the building facade. The orientation of the facade was parallel to the road and the anechoic room floor was covered in a linoleum surface which was highly reflecting, the effective height of a vehicle source was arranged to be 0.8m. The receiver condenser microphone was fixed at a height of a seated person.

Figure 4 shows measured attenuation of thnadner and solid wall configurations when the depth of the courtyard is 5m. The effectiveness of the solid walled courtyard is higher at most frequencies than that of the thnadner. However, a sharp decrease in the protection of the solid wall is observed at high frequencies and at 2.4m from the initial vehicle position. Figure 5 shows a comparison between measured internal attenuation dB(A) for the thnadner and solid wall for the 5m configuration.

Buildings with Balconies

In a later experiment the attenuation experienced inside the receiving room resulting from the presence of the balcony was determined. Two balcony types were chosen (thnadner and solid wall) for different levels of floors. Generally, the protection of the solid wall is greater than that of the thnadner. The difference is appreciable when the position of the vehicle is perpendicular to the centre line of the facade. For the first and second floor the protection of the thin walled balcony is generally greater than that of the thnadner balcony and the difference lies between 1 to 5 dB.

However, the protection afforded by both configurations is almost identical at third floor level (see Figure 6) especially where the vehicle position is perpendicular to the centre line of the facade. The correlation observed for the 'A' weighted attenuation is high with the coefficient of correlation being 0.99. Considerable scatter in the results is noticeable for the first floor case where the coefficient of correlation is 0.68. However, at the second floor level the agreement between the performance of the two screens is quite good where the coefficient of correlation is 0.94. It is noticeable that the attenuation sharply decreases as the source distance increases. It can be concluded that a thnadner balcony can be effective at higher floor levels.

CONCLUSION

The results of the acoustic scale model experiment have demonstrated that the attenuation provided by a thnadner is more effective when the pitch is small. For a thnadner to be effective, it is suggested that the pitch should be less than half the wave length of dominant frequency of the noise source. For the case of road traffic this means a pitch of less than 0.3m.

A comparison of the performance of both thnadner screens and solid walls used as the walls of courtyards and balconies of self-protecting buildings has shown that thnadners can usefully be employed as the screening elements against traffic noise. Since the need for ventilation is often found to conflict with acoustic requirements, the use of thnadner screens as a means of achieving passive acoustic protection might offer some advantages over solid walls.

REFERENCES

[1] Wirt, L.S., "The control of diffracted sound by means of thnadners (shaped noise barriers) Acustica", 42, pp. 73-88 (1979).

[2] Seuss, Dr., "On beyond Zebra", Random House, New York (1955).

[3] May, D.N. and Osman, M.N., "Highway noise barrier new shapes", J. Sound Vib. 71 (1), pp. 73-101 (1980).

[4] Hutchins, D.A., Jones, H.N. and Russell, L.T., "Model studies of barrier performance in the presence of ground surface (Part 2) different shapes", J. Acoustic Soc. Am. 75, pp. 1817-1826 (1984).

[5] Gibbs, B.M. and Hammad, R.N.S., "The acoustic performance of building facades in hot climates Part 1 - Courtyards", Applied Acoustics, 16, 121-137 (1983).

[6] Delany, M.E., Rennie, A.J. and Collins, K.M., "A scale model investigation of traffic noise propagation", NPL Acoustics Report AC 58 (1974).

[7] Oldham, D.J. and Mohsen, E.A., "The acoustical performance of self-protecting buildings", J. Sound Vib. 65 pp. 557-581 (1979).

[8] Gibbs, B.M. and Hammad, R.N.S., "The acoustic performance of building facades in hot climates Part 2 - Closed Balconies", Applied Acoustics 16 pp. 441-454 (1983).

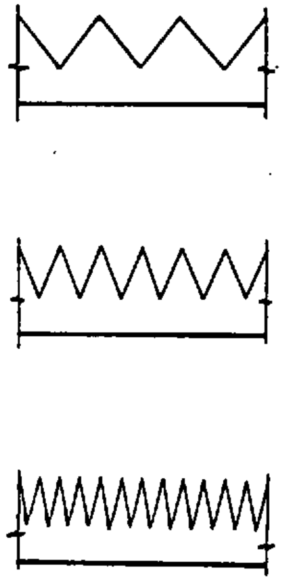

FIGURE 1 ELEVATIONS OF MODEL BARRIERS.

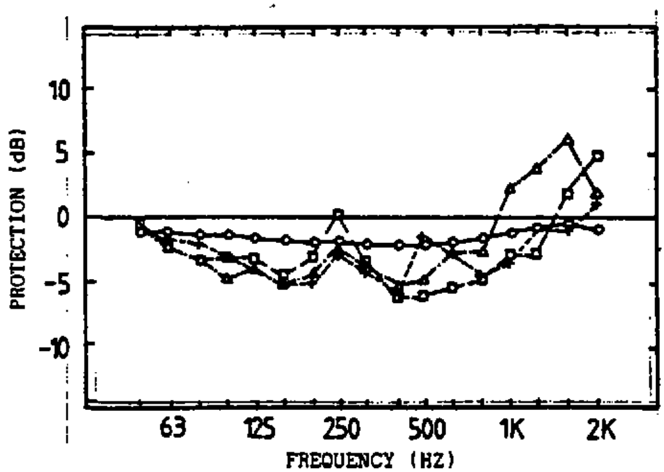

FIGURE 2 COMPARISON BETWEEN MEASURED AND PREDICTED PROTECTION OF THNADNER SCREENS FOR GEOMETRIES SHOWN. O, PREDICTED, MEASURED, +, THNADNER 1, □, THNADNER 2, Δ, THNADNER 3.

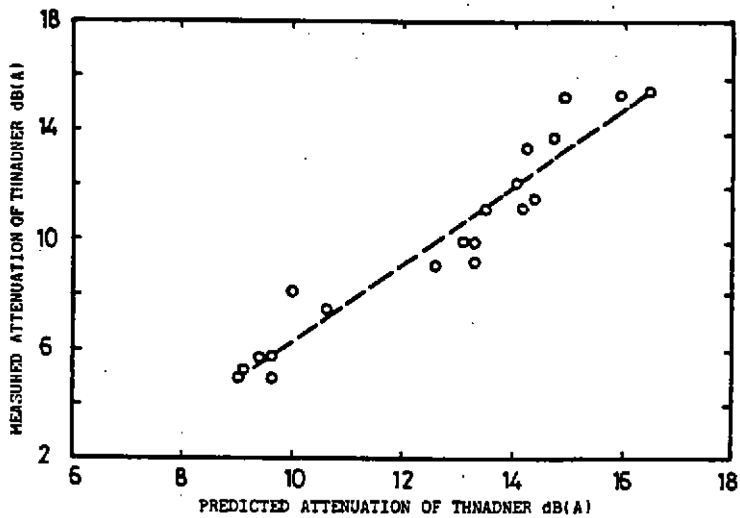

FIGURE 3 CORRELATION BETWEEN MEASURED AND PREDICTED PROTECTION AFFORDED BY THNADNER 3.

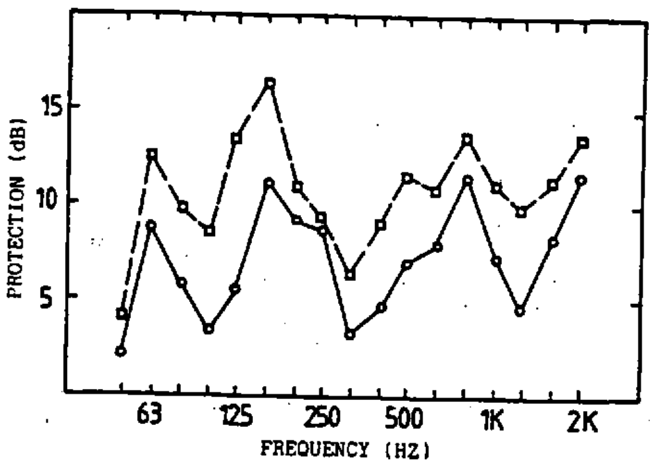

FIGURE 4 COMPARISON BETWEEN MEASURED PROTECTION AFFORDED BY SOLID WALL AND THNADNER COURTYARD OF DEPTH (5m), ⊙, THNADNER COURTYARD, ◻, SOLID WALL COURTYARD.

THE USE OF THNADNERS FOR THE CONTROL OF NOISE FROM ROAD TRAFFIC

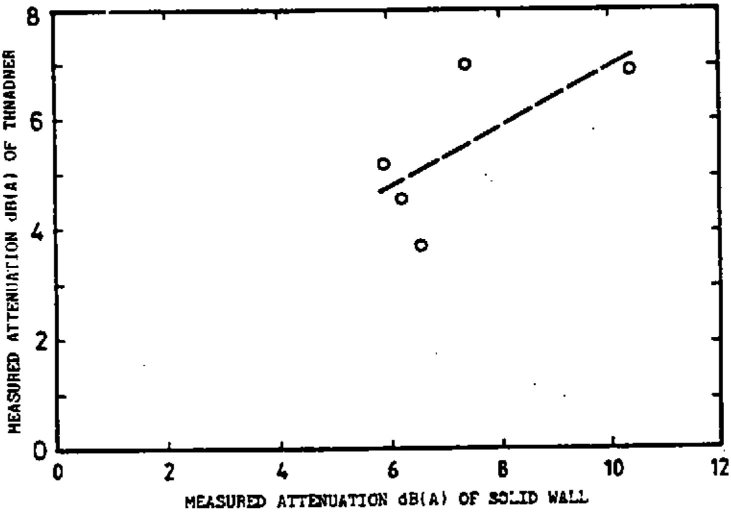

FIGURE 5 CORRELATION BETWEEN MEASURED PROTECTION AFFORDED BY SOLID WALL AND THNADNER COURTYARD FOR DEPTH OF (5m).

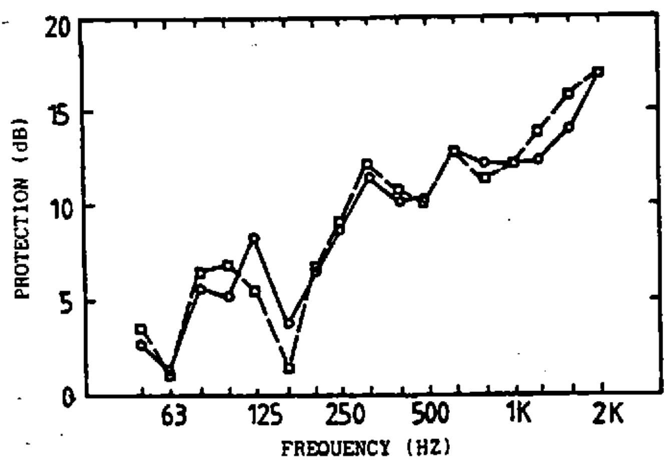

FIGURE 6 COMPARISON BETWEEN MEASURED PROTECTION AFFORDED BY SOLID WALL AND THNADNER BALCONY AT THIRD FLOOR LEVEL
○, THNADNER, □ , SOLID WALL.