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NUMERICAL MODELLING OF T-PROFILE BARRIER DESIGNS

D C Hothersall, D H Crombie, S N Chandler-Wilde

Department of Civil Engineering, University of Bradford, Bradford, West Yorkshire BD7 1DP

1. INTRODUCTION

The addition of a horizontal cap to a conventional barrier, thus creating a 'T-Profile' design (as shown in Fig. 1), has been the subject of a limited number of previous studies [1-4], encompassing either acoustical scale modelling, full scale field measurements, or both. In general, it has been established that a design of this kind is likely to achieve a small gain in Insertion Loss over a conventional barrier of the same height, although the results from full scale field measurements have been modest, typically around 1 - 1.5 dB(A) or less.

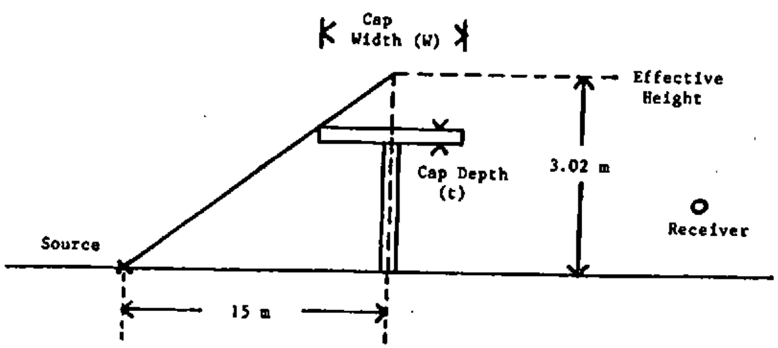

Figure 1 - The two-dimensional model, illustrating the concept of 'Effective Height' of the barrier.

A numerical model has been developed which enables the Insertion Loss of T-Profile and associated barriers to be calculated for a point source of sound, with a higher degree of accuracy than was previously possible. The effects of ground cover and absorption along the upper surface of the barrier cap are also considered. Insertion Loss is calculated at 1/3 octave centre frequencies, thus allowing spectral content to be considered as well as results for a broad band source which represents A-weighted road traffic noise.

Previous research has centred around the scale model experiments of May and Osman [1], which showed great promise for T-Profile designs. Increases in Insertion Loss of the order of 2.2 dB(A) for only a 0.41 m total cap width, and 6.4 dB(A) for a 4.88 m cap width were observed. Also, when the upper surface of the caps were treated with a strong absorbent material, the respective increases were greater still. However, the results of full-scale experiments [2,3] and other scale models [3,4] have proven disappointing, falling well below those obtained by May and Osman. May and Osman also studied the effect of sloping the arms of the cap by 14^{o} to the horizontal, thus creating Y- and Arrow-Profile designs. They found that the T-Profile performed significantly better than the Y-Profile which in turn performed significantly better than the arrow shaped Profile.

It should be noted that throughout May and Osman's experiments the barrier height was kept constant at 4.9 m. However, this means that for different barriers, the path difference between the direct ray from source to receiver and the rays grazing the edges of the barrier, can vary considerably between, for example, the 0.41 m and the 4.88 m capped T-Profiles mentioned above. In the numerical model, use was made of the concept of 'effective height' for every barrier considered, which reduces the effect of path differences. This was achieved by projecting the ray from the source to graze the edge of the barrier. The intersection of this ray with the centre line of the barrier defines the height and position of an equivalent, infinitely thin, vertical barrier. Thus, the projected rays, for every barrier design, were modelled to intersect the centre line at an effective height of 3.02 m. This meant for example, that for T-Profile designs with cap widths of 1, 2 and 3 m, the physical heights were 2.92, 2.82 and 2.72 m respectively. Strictly, the intersection of rays from source and receiver which graze the edges of the barrier define the top of the equivalent barrier but the centre line was chosen as a compromise for the intersection, as results were calculated simultaneously for nine different receiver positions. Although this resulted in some variation in path difference, the error was never greater than 0.03 m, which can be related to a maximum error in Insertion Loss of about 0.5 dB(A). The concept of effective height is shown in Fig. 1.

2. NUMERICAL MODEL

The numerical model has been described in detail elsewhere [5,6]. Figure 1 shows the two-dimensional configuration which is considered. The barrier is situated on a flat plane of uniform admittance. The coordinates of the corners of the barrier are input as data for the model and the surface characteristics in the form of the acoustic admittance of each linear surface segment can be defined separately. For a given source position, using a boundary element method of solution of a developed form of the Kirchoff-Helmholtz integral equation, it is possible to calculate approximately the pressure at points on the surface of the barrier. The points selected are at intervals of $\lambda/5$ along the segments, where λ is the wavelength of the source. By proper formulation of the problem only elements over the barrier surface need to be considered and not those in the ground surface.

Having obtained the pressure in the surface of the barrier the pressure at a receiver point in or above the ground surface can be obtained from the integral equation. For short wavelengths and large barriers the expense in terms of computing time and storage to solve the problem can be considerable.

Results are presented in terms of Insertion Loss defined by

$$IL = 20 \log_{10} \left[\frac{p_g}{p_b} \right] \text{ dB}$$

where p_g is the acoustic pressure at the receiver for the given source position with the flat ground present and p_b is the pressure when the barrier is introduced. The wave solution obtained by this method results in a complicated pressure field when the effects of diffraction by the barrier are combined with reflection from the ground surface if the source and receiver are above the ground.

The source was positioned in the ground surface at 15 m from the centre line, for every barrier considered. The pressure at 9 receiver positions was calculated at heights of 0, 1.5 and 3 m above ground and 20, 50 and 100 m from the centre line of the barrier. Two ground types were considered, 'hard ground' with zero admittance and 'soft ground' with admittance defined by the empirical relations of Delany and Bazley [7] derived for fibrous materials with a flow resistance parameter of σ = 250,000 SI. This is commonly used to characterise grassland surfaces.

All the barrier shapes were symmetrical about the centre line and the effects of various absorbent treatments to the upper surfaces were considered. For convenience these were defined in terms of the Delany and Bazley expressions for acoustic admittance, using the values for the parameters given in Table 1. These can be approximately related to the statistical absorption coefficient [8] which is a commonly quoted parameter for such materials. An approximate mean value of the absorption coefficients over the range of frequencies considered for the four different treatments is also given in Table 1.

At each of the receiver positions the Insertion Loss was determined for each of the 1/3 octave centre frequencies between 63 H_Z and 3.16 KH_Z. The Insertion Loss for a broad band noise source was obtained by applying the calculated results at 1/3 octave centre frequencies to a 1/3 octave,

SURFACE TREATMENT	FLOW RESISTANCE σ SI	DEPTH (m)	MEAN STATISTICAL ABSORPTION COEFFICIENT $\bar{\alpha}$
1	00	0	0.0
2	2,00,000	0.1	0.4
3	20,000	0.1	0.8
4	200	10.0	0.95

Table 1 - Parameters used to describe the four different surface treatments used.

A-weighted spectrum of road traffic noise.

3. RESULTS

In order to derive results which provided information about the overall effectiveness of the different barrier shapes, the mean Insertion Loss was calculated for the six receiver positions above the ground. The results for T-Profiles are plotted in Figure 2 and show the variation with the width of the upper surface of a T-shaped form and the effect of treatment on the upper surface. A conventional, reflective wall barrier with width, w = 0.2 is also indicated, as is a similar barrier which tapers to a point over the upper 0.5 m, giving w = 0. For the reflecting upper surface and surface treatment 2 the effect of increasing the cap width is negligible.
For treatments 3 and 4 a progressive improvement in Insertion Loss is observed and this effect is related to cap width. On comparing the results for hard and soft ground surfaces there is a significant absolute difference in results of around 6.5 dB(A). However, the relative trends for the two sets of results are remarkably similar.

In Figure 3 the mean broad band Insertion Loss over the six receiver positions above the ground is plotted as a function of the slope of the cap arms, θ. The total width of the upper surface of the barrier is 2 m. Again allowance for effective barrier height has been made as described in section 1. For $\theta = \pm 90^{\circ}$ the results appear to converge in a region very close to the value for a reflecting thin screen. For a totally reflecting ground surface the arrow shape performs less efficiently than the T shape for all value of θ. For the Y shape some marginal improvement in Insertion Loss is observed when the upper surface is strongly reflective,

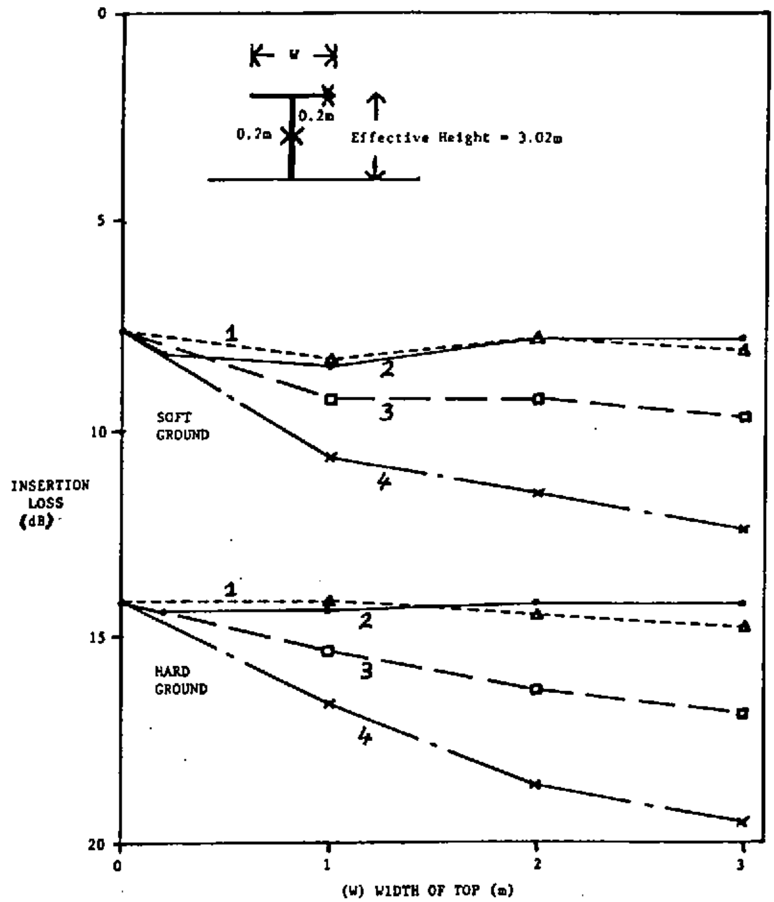

Figure 2 - Mean Insertion Loss for a broad band source as a function of the cap width (W). The effect of the four different absorptive treatments (detailed in Table 1) are also shown for both hard and soft ground cover.

but not for efficiently absorbing surface treatments. Fewer points were calculated for the case of soft ground but they indicate a similar trend.

The results of model experiments [1] provided some evidence that a significant improvement in Insertion Loss could be obtained by the application of a horizontal reflecting cap of limited width (about 0.6)

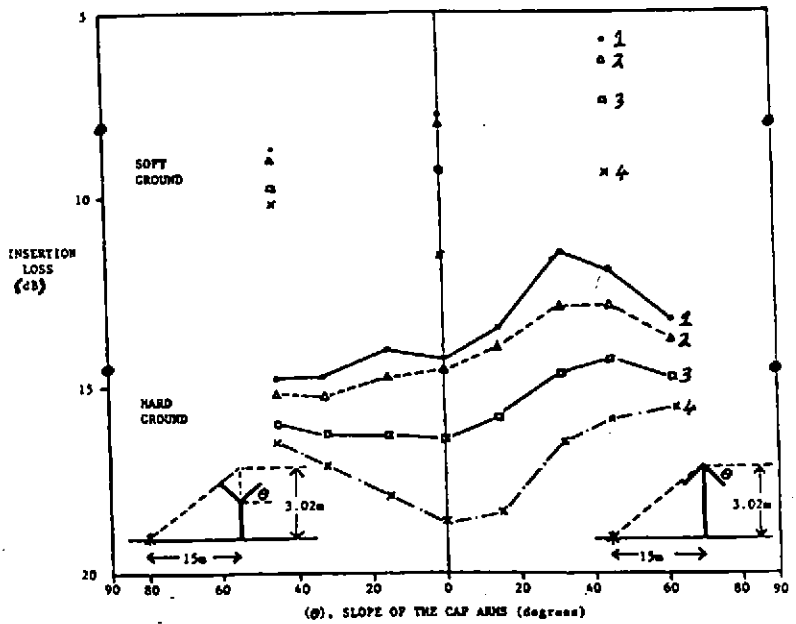

Figure 3 - Mean Insertion Loss for a broad band source spectrum plotted as a function of the slope of the cap arms (θ). The four different absorptive treatments are also shown for both hard and soft ground cover. The values for a reflecting thin screen (●) are also indicated.

to the top of a vertical wall barrier. It was also argued that the improvement would be greatest if the depth of the cap was kept to a minimum, or, effectively zero. Although this treatment appeared very cost effective, full scale trials proved disappointing, giving only marginal increases in Insertion Loss of about 1.0 - 1.5 dB(A) for a 0.019 m deep, 0.75 m wide cap [2] and about 1.0 dB(A) for a 0.08 m deep, 1.0 m wide absorptive cap [3].

A series of numerical simulations was carried out to investigate any possible benefits that may be obtained from very thin horizontal caps. Figure 4 shows the mean Insertion Loss for the 6 standard, above ground receiver positions for the source with the broad band spectrum. In every case the height of the barrier was adjusted to allow for the path difference effect. Insertion Loss is plotted against cap width for horizontal caps which were 0.2 m and 0.01 m thick. The results indicate only a marginal increase in Insertion Loss associated with the reduced cap thickness at these receiver positions. Similarly, negligable difference was found between a conventional wall barrier of width 0.2 m, and one of

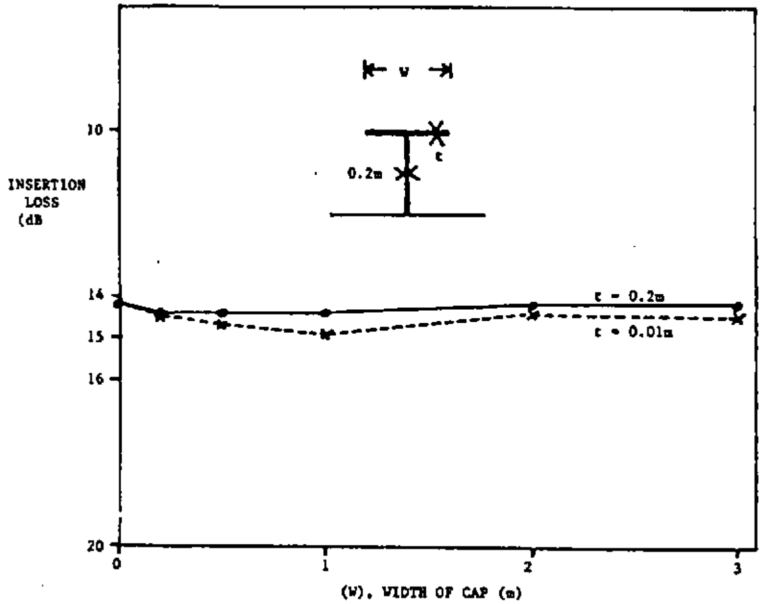

Figure 4 - Mean Insertion Loss for T-Profile barriers plotted as a function of cap width (W) and cap depth (t), for a broad band source spectrum.

width 0.01 m.

4. CONCLUSIONS

Detailed information has been obtained regarding the performance of T-shaped and associated barriers in attenuating sound. The computer model is two-dimensional, but the results obtained are expected to relate with some accuracy to the Insertion Losses for an infinitely straight barrier of uniform section and a point source of sound [5,9]. The results from the model are not applicable in terms of absolute values to the incoherent line source configuration which would model a traffic flow. However, it is expected that the relative performance of respective barriers will be similar to that observed from the use of the model [1,4].

From this study the following conclusions are drawn:

1) For reflective T-Profile barriers the Insertion Loss is constant with respect to the cap width provided that the barrier height is adjusted so that the path difference is approximately constant. The path difference is defined as the difference in length between the direct ray from source to receiver and the path via the rays grazing the barrier.

2) The introduction of a weakly absorbing upper surface to a T-Profile barrier produces no significant improvement in Insertion Loss whereas strongly absorbent surfaces produce progressive increases. Also, the effect increases with the width of the cap.

3) When the T-Profile was modified to an Arrow-Profile, a significant reduction in Insertion Loss was observed. This trend also occurred for the Y-Profile when the upper surfaces were strongly absorbing (Fig. 3).

4) Comparison of results for barriers with 'wedge shaped' and 'flat topped wedge mounds' [5] indicate that for the same broad band source over hard ground, the Arrow- and T-Profiles performed significantly better than their counterparts with similar upper sections, the difference being around 1-2 dB(A).

5) For a reflective T-Profile barrier, changing the depth of the cap from 0.2 m to 0.01 m has a negligable effect upon the Insertion Loss, at the receiver points monitored and for a broad band point source of sound.

Acknowledgement

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5. REFERENCES

1) D.N. MAY and M.M. OSMAN. 1980 Journal of Sound and Vibration 71, 73-101. Highway noise barriers: New shapes.

2) D.N. MAY and M.M. OSMAN. 1980 Journal of Sound and Vibration 71, 65-71. The performance of sound absorptive, reflective and T-Profile noise barriers in Toronto.

3) J.J. HAJEK and C.T. BLANEY. 1984 Transportation Research Record 983, 8-17. Evaluation of T-Profile noise barriers.

4) D.A. HUTCHINS, H.W. JONES and L.T. RUSSELL. 1984 Journal of Acoustical Society of America 75 (6), 1817 - 1826. Model studies of barrier performance in the presence of gorund surfaces. Part II - Different shapes.

5) D.C. HOTHERSALL, S.N. CHANDLER-WILDE and N.M. HAJMIRZAE. 1989 Submitted for publication to Journal of Sound and Vibration. Efficiency of single noise barrers.

6) D.C. HOTHERSALL, S.N. CHANDLER-WILDE and N.M. HAJMIRZAE. 1989 Proceedings of the Institute of Acoustics, 11 part 5, 207-214. Numerical modelling of noise propagation over barriers.

7) M.E. DELANY and E.N. BAZLEY. 1970 Applied Acoustics 3, 105-116. Acoustical properties of fibrous absorbent materials.

8) D. ABIES and G.H. HANSEN. 1980 Applied Acoustics 13, 357-391. Flow resistance information for acoustical design.

9) A. DAUMAS, 1978 Acoustics 40, 213-222. Etude de la diffraction par un é mince disposé sur le sol.