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EFFECTIVENESS OF NOVEL SHAPED BUNDS IN REDUCING TRAFFIC NOISE

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1. INTRODUCTION

Earth bunds are the most widely used method of noise control in the UK and many other countries due to their low cost, low maintenance, relatively pleasing appearance and the support of a wide range of flora and fauna. Little effort has been made into designing more efficient shapes, which can improve on the noise screening of standard designs of bund. The use of recent developments in boundary element methods (BEM) and the advent of relatively cheap, high speed computing have enabled predictions to be made of the screening performance of large and complex shaped bunds. The paper reports on the results of modelling a range of modified bunds in order to identify acoustically efficient yet practical designs.

2. BEM MODEL DESCRIPTION

Essentially, the method divides the surfaces in the road cross-section into a large number of elements and calculates the sound field at a particular frequency by solving a reformulation of the Helmholtz wave equation in terms of an integral equation. The surfaces including barriers and bunds are divided into boundary elements of length no greater than $\lambda/5$ where λ is the wavelength. The effects of ground cover and absorptive surfaces can be included in the definition of the elements. A full description of the approach has been previously given [1].

In this study a dual 3-lane motorway has been modelled according to the Department of Transport's standard cross-section for a rural motorway. Based on previous work [1] the vehicle source used in most cases examined was based on a light vehicle shape with sources at a height of 0.05m above the road under the nearside and farside edges of the vehicle body. Some runs were carried out with a heavy vehicle shape. The source spectra for light and heavy vehicles were based on those measured at the edge of a motorway. It was found that predictions for the heavy vehicle source gave similar results to those using the light vehicle source and in this paper only the results for the light vehicle shape are given. The sources are two-dimensional, which means that the traffic is modelled as a coherent line source. Despite this limitation, results have shown good agreement with measured values. The road surface was assumed to be acoustically hard and the verge, bund and flat ground beyond the bund to be acoustically soft with an average statistical absorption coefficient from 100Hz to 5kHz of 0.37. Separate runs were carried out with the vehicle in each carriageway 3.5m from the carriageway edge. The resulting noise levels were then combined to represent the overall effect of motorway traffic.

3. SCREENING OF NOVEL SHAPED BUNDS

Calculations were carried out for various shapes of bund. The changes in insertion loss produced by altering the shape of a standard bund, were calculated for the A-weighted level and third-octave band levels from 100Hz to 5kHz. The method described in ISO 9613-1 [2] was used to take account of air absorption and for this purpose a standard set of conditions of 15 deg C and 50% humidity was assumed. The differences in insertion loss were calculated at receiver heights of 1.5 and 4.5m above ground level at distances up to 1280m from the edge of the road verge. The standard bund shape shown in Figure 1(a) was 3m high with a 3m wide top, with front and rear slopes of 20 degrees giving a base of 19.5m.

3.1 Gains in Insertion Loss with Variations in Top Profile

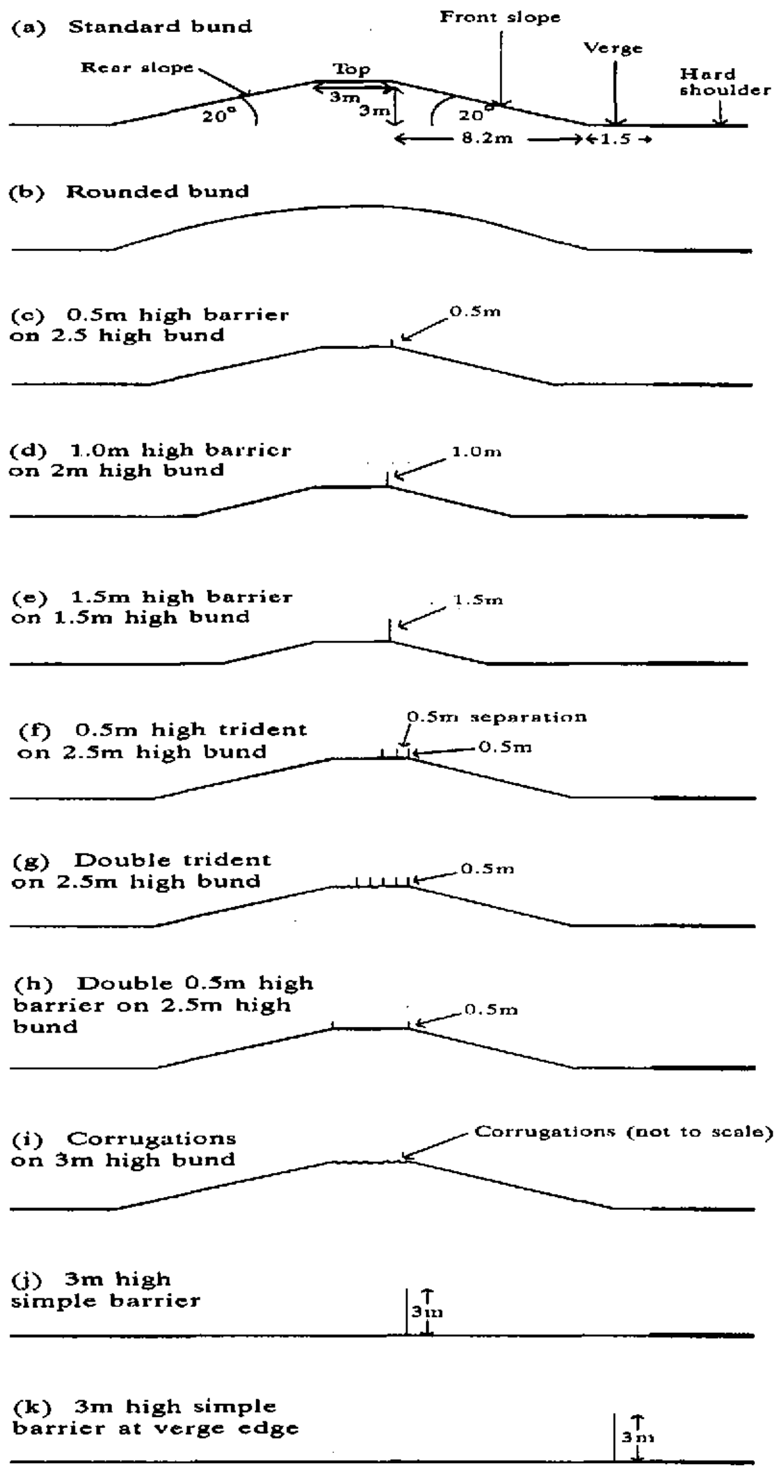
Changes in the top profile of the standard bund were produced by lowering the height and adding simple barriers so that the overall height remained at 3m. The position of the leading diffracting edge was always at the position of the front edge of standard bund top i.e. at a distance of 8.2m from the verge. This was necessary for a fair comparison of options since displacing the diffracting edge closer to the noise source, is known to increase screening. Figures 1(b) to 1(k) show the shapes that were examined. These included a multiple edge profile (trident) which has been used in previous work to increase the performance of simple barriers [3,4]. This profile had the standard dimensions of 0.5m high panels at 0.5m centres and is shown in Figure 1(f). A double trident (Figure 1(g)) was produced by adding a further 2 panels. A corrugated surface (Figure 1(i)) with the grooves running parallel to the road was also introduced on the top surface of the standard bund. Previous work had indicated the potential benefits of such corrugations for noise control [5]. The grooves were 0.04m deep and 0.16m wide and spaced at 0.32m centres.

The changes in the A-weighted insertion loss produced by altering the shape of the standard 3m high bund are plotted for 1.5m and 4.5m high receivers in Figures 2a and 2b respectively. All references to levels in dB in the text below should be taken to mean the A-weighted level.

At the 1.5m receiver height the largest increase in screening of over 5dB was predicted at 20m for the double trident shape. The gain reduced steadily with distance although it was still significant (2dB) at 300m from the verge. The single trident performed slightly worse than the double trident and the two 0.5m high barriers located at the edges of the top (shown in Figure 1(h)) were only slightly less effective than the single trident. At most distances single barriers of heights 0.5, 1 and 1.5m at the front edge of the bund (illustrated in Figures 1(c), 1(d) and 1(e) respectively) generally improved screening by relatively small amounts. However at the largest distance the 1.5m barrier increased screening by 2dB. The introduction of the corrugated surface on the top surface of the bund had little effect at most distances although as distance increased there was a steady improvement so that at 1280m there was a 2.5dB improvement. The trend in insertion loss was similar to that described for the single 1.5m barrier. A bund with a rounded top was very slightly less efficient than the standard bund at all distances. For comparison with other methods of screening, results for a simple 3m barrier were included (shown in Figures 1(j) and 1(k)). With the barrier placed at the position of the front edge of the standard bund i.e. 8.2m from the verge edge, performance is similar to that of the standard bund with corrugations on the top surface. However, if the barrier is placed at the verge edge then there are gains at all distances with small increases in insertion loss close to the verge increasing to over 3dB at the greatest distance studied.

At the 4.5m receiver height there were only small improvements in insertion loss for the modified bunds at small distances. The largest gains were found at mid distances and a gain of 3dB was predicted for the double trident shape at 160m. Generally the relative effectiveness of the options were similar to that found at the 1.5m height. The largest gain was predicted at 20m for the 3m high barrier at the verge. This gain in insertion loss decreased rapidly to a minimum of just over 1dB at 160m but increased to over 2dB at the greatest distance (1280m).

Figure 1: Bunds with modified tops

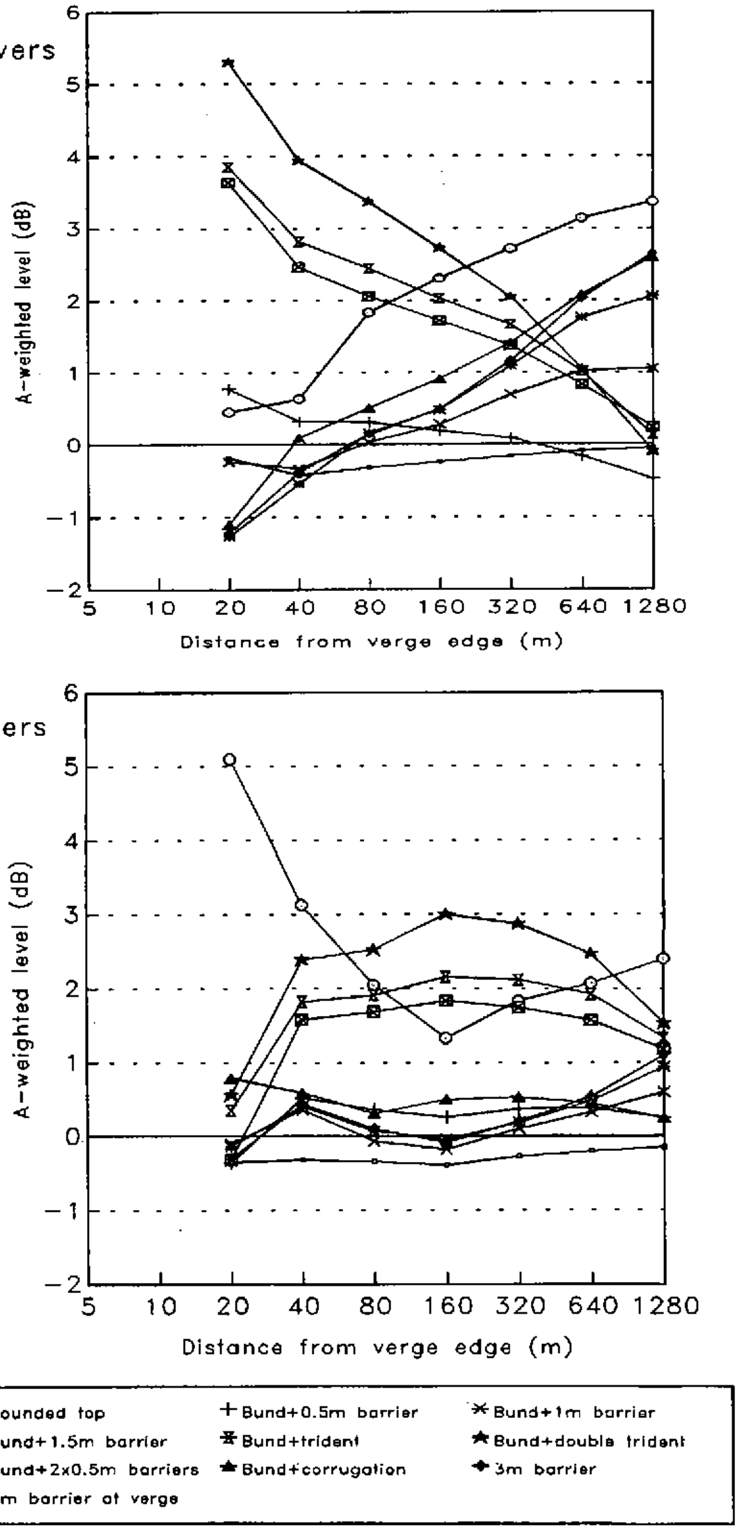


Note that the leading diffracting edges are placed at 8.2m from verge edge except for rounded bund and 3m high barrier at verge edge.

Figure 2: Insertion loss gains for modified bunds with overall height of 3m

(a) 1.5m receivers

(b) 4.5m receivers



Comparisons are made with the 3m high standard bund

3.2 Gains in Insertion Loss with Absorptive Material

Figures 3a and 3b show the insertion loss gains produced by applying a highly absorptive material (average statistical absorption coefficient of 0.75) to the standard grass covered bund. At the 1.5m receiver height the most significant effect was obtained with absorptive material covering all surfaces. Gains of more than 4dB were predicted at all distances with a maximum gain of over 8dB. Treating the front and top slope lowers the gain by about 2dB at the shortest and largest distances but the difference was fairly small at mid distances. It is not likely to be cost effective to treat slope areas with absorptive material but treating the top 3m wide surface may be feasible. If only the top was treated the gain was 5dB at the closest distance to the road, falling steadily to less than 1dB at the furthest distance. Treating the front slope only produced a fairly steady improvement with distance of approximately 2dB. Treating the rear slope only was generally not so effective as treating the front slope. A less absorptive treatment (average statistical absorption coefficient of 0.64) to the top of the bund produced a gain of 2dB at the closest distance falling steadily to zero at the largest distance.

At the 4.5m receiver height there was much less variation of the additional screening performance with distance. The smallest improvements were at the 20m position. It can be seen there is little difference between treating the whole bund and treating the front and top only. Both options gave increases in screening of 3 to 4dB beyond 20m. Treating the top surface generally produced a significant improvement of 2 to 3dB. However, the remaining options produced improvement of about 1dB or less.

3.3 Gains in Insertion Loss with Slope Angle

A series of narrow bunds were created by steepening both front and rear slopes and reducing the top surface to 1m in width. These were displaced to the verge edge as shown in Figure 4a to 4e. Figures 5a and 5b show the gains in insertion loss with distance produced by these changes to the standard bund. The bund with the greatest slope (80 degrees) produced the largest gain in insertion loss. With the narrow top the bund with the same 20 degree slopes was less efficient at all distances than the standard bund with the 3m wide top. If the front diffracting edge of the bund with 80 degree slopes is displaced to the position of the standard bund it can be seen that much of the improvement is removed. This highlights the importance of placing the diffracting edge as close to the source as practicable.

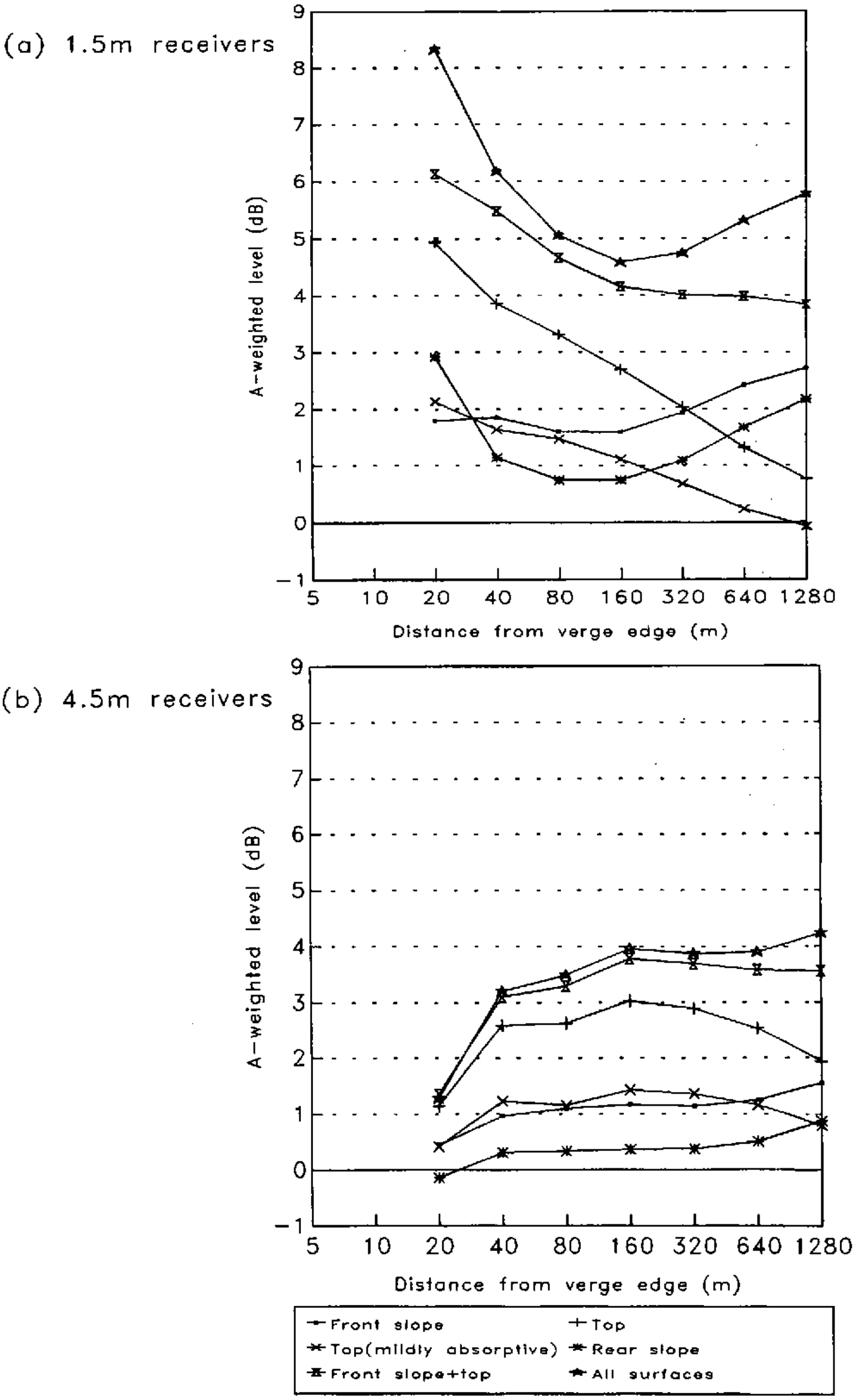
3.4 Comparison of the Most Effective Bund Shapes with Higher Bunds

Higher bunds are the most obvious way of improving screening. However the volume of material required rises with the square of the height for standard shaped bunds with 3m wide tops and 20 degree slopes. In addition any improvements in screening performance will be moderated by the displacement of the diffracting front edge away from the road as the height increases. The performances of taller standard bunds of height 3.5m, 4m and 5m are compared with the most effective 3m high bunds studied previously in Figures 6a and 6b.

At the 1.5m receiver height the absorptive top and double trident had similar performance and provided better screening than all the taller bunds examined at nearly all distances. The bund placed at the verge edge with the 80 degree slope performed better than the taller bunds at distances of 160m or greater.

At the 4.5m high receiver position the tallest bund provided better screening than any of the other options at distances up to 160m. The improvement was particularly marked at the closest distance of 40m where screening performance was 3dB or greater than the 3m high bunds. All the 3m high bunds

Figure 3: Insertion loss gains for bunds with absorptive treatments



Standard bund is 3m high with 3m wide top and 20 degree slopes

Figure 4: Bunds with different slope angles and narrow top

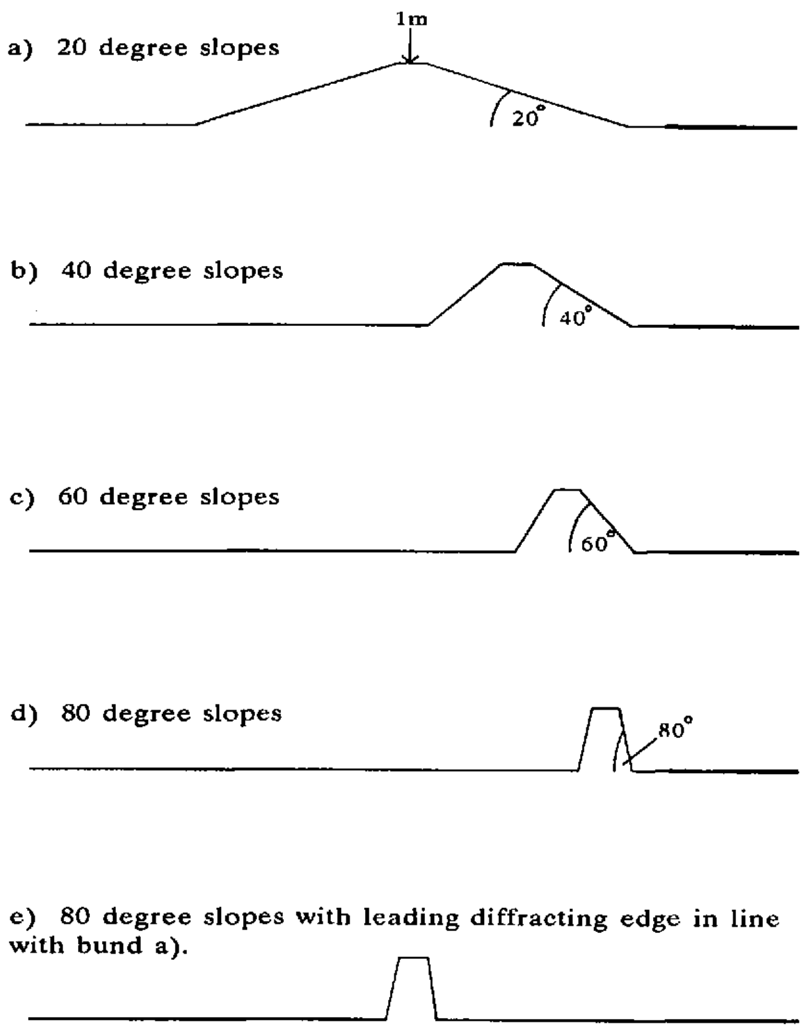
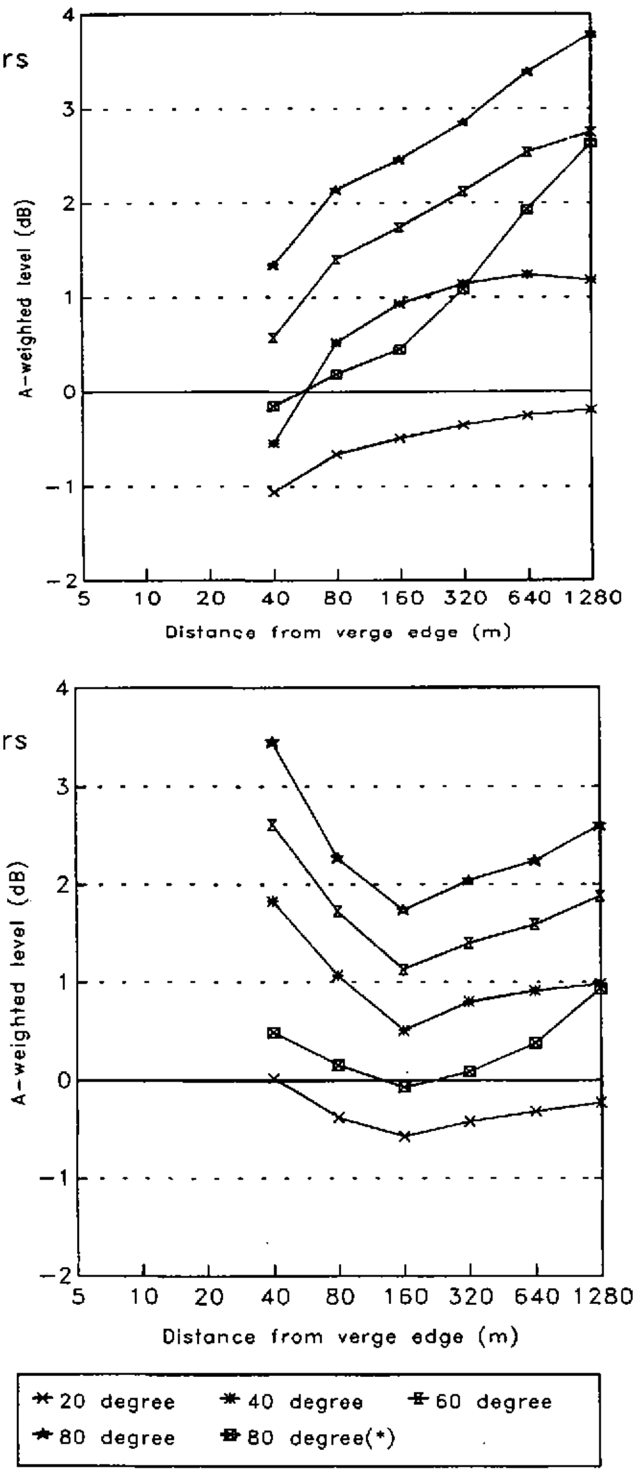


Figure 5: Insertion loss gains for narrow bunds adjacent to verge

(a) 1.5 receivers

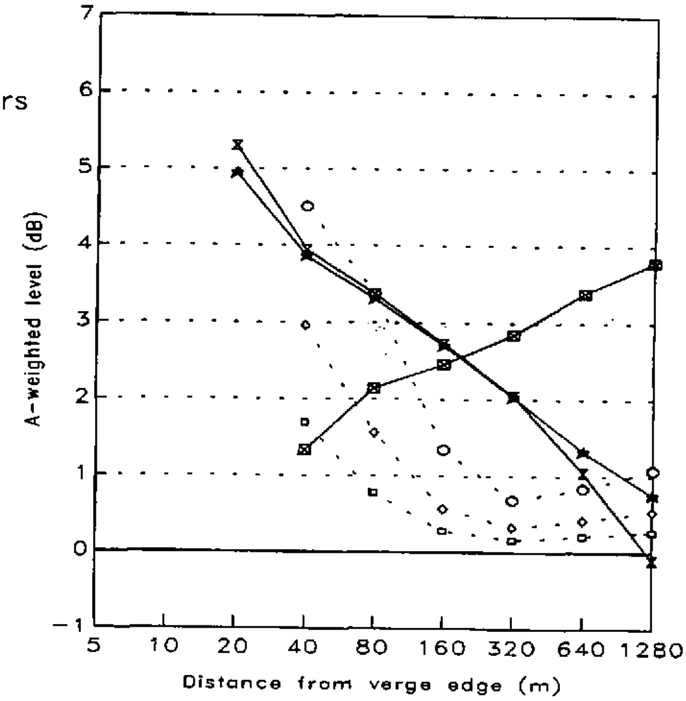
(b) 4.5m receivers



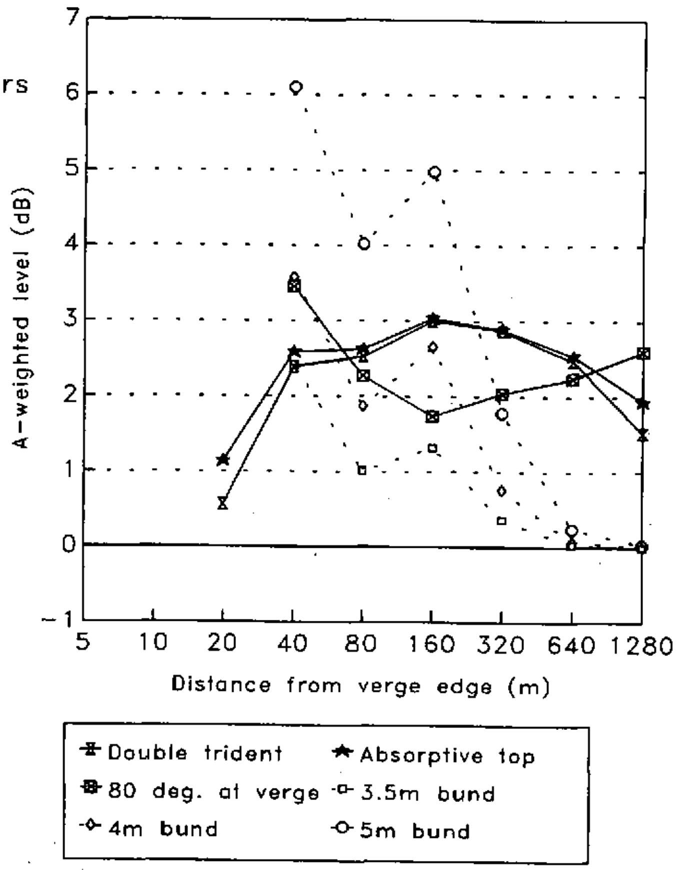
Standard bund is 3m high with 3m wide top and 20 degree slopes
80 degree(*) is bund with 80 degree slopes with leading edge at 20 degree bund position

Figure 6: Insertion loss gains of higher and modified bunds

(a) 1.5m receivers



(b) 4.5m receivers



Comparisons are made with the 3m high standard bund produced gains of approximately 2dB or greater at 320m and beyond while the gains for all the taller bunds reduced rapidly with increasing distance. The bunds with the double trident and absorptive top performed better than the 3.5 and 4m high bunds at nearly all distances.

4. CONCLUSIONS

Using the Boundary Element Method predictions have been made of the effects of altering the shape and surfaces of roadside bunds. The main conclusions are:

1. A trident shape consisting of three 0.5m high barriers placed at 0.5m centres on the top of a bund improved screening by a significant amount compared with a bund of the same overall height. Introducing two further barriers of the same dimensions to form a double trident improved screening to a maximum value of over 5dB at 20m reducing to 3dB at 160m.

2. Applying absorptive material to the top of the bund improved screening to a similar degree as the double trident. However, the treatment needs to have very good absorption characteristics to achieve this performance. Applying absorptive treatments to other bund surfaces is not as effective.

3. The predicted screening of bunds can be enhanced by steepening the front slope so that the front top edge can be brought closer to the traffic source.

4. Similar or greater gains than achievable by increasing the height of a standard bund to 5m can be obtained at most receiver positions examined by the double trident shape mounted on a 2.5m high bund.

5. Using the BEM approach it is possible to optimise the bund shape to provide maximum benefit for communities requiring protection from noise.

5. ACKNOWLEDGEMENTS

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6. REFERENCES

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