# MODEL INVESTIGATIONS OF THE PERFORMANCE OF RAILWAY NOISE BARRIERS

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## 1. INTRODUCTION

Noise from railways is an increasing problem, especially near high speed tracks with heavy traffic. In view of the localised nature of the source barriers offer a potentially efficient method of alleviating the noise problem. Barriers have been widely employed to reduce the impact of road traffic noise and are increasingly being used alongside railways particularly in Europe and Japan.

Noise from trains is generated from three main sources i) rail wheel interaction ii) aerodynamic effects and iii) power units. Rail wheel noise is localised. Aerodynamic noise sources are distributed over the surface of the train and are significant at high speed. Both the source position and emission characteristics of power units depend on the individual train type. Only rail wheel noise will be considered here since it is this which is generic and which noise barriers of restricted height are primarily aimed at reducing.

The major factors affecting the performance of a noise barrier are the height and the proximity to the source. For railways, operational considerations mean that the position of barriers is controlled by the structure gauge [1]. It is also common to restrict the height so as not to impede the view of passengers. It is important to develop designs of noise barrier which will produce optimum performance within these restrictions. Several modifications are possible to the simple plane rigid screen. The purpose of this paper is to investigate the performance of several designs of barrier in reducing noise. Comparisons of performance could be carried out using site tests. These are very expensive and time consuming. Also the results are affected by atmospheric and other site conditions which add extra variables to the data and hinder comparison. The method used here is to model the conditions by numerical and experimental methods. Although the results depend on the accuracy of the models extraneous factors which affect the site results can be avoided.

## 2. MODELLING METHODS AND RESULTS

### 2.1 Numerical Modelling

A 2D boundary element method is used which has been reported in [2]. The model uses a boundary integral equation formulation to calculate the sound field for a point source and a given distribution of surfaces situated on a ground plane. Figure 1 shows a cross section which has been used. The profile of the train is typical of a BR Mk IV carriage and 225 tractor unit. Four different barrier shapes are also indicated. These have been positioned so that they are as near to the track as possible but no part of the barrier violates the structure gauge. The height of the barriers is identical and the top edge is at the level of the bottom of the carriage windows. The BE model is able to simulate surfaces of finite impedance. Over the area of the dotted line in Figure 1 a surface impedance appropriate for track ballast was used. The impedance was calculated using the model of Attenborough [3] with effective flow resistivity of $180000\,Nsm^{-4}$, porosity 0.4, tortuosity 0.5 and pore shape factor 0.5. The remaining ground surfaces were grassland with a flow resistivity of

125000 $Nsm^{-4}$, porosity 0.5, tortuosity 1.67 and shape factor 0.5. Two dipole sound sources were assumed [4], one at each railhead and with an emission spectrum characteristic of BR Mk III disc-braked rolling stock [5]. For noise barriers with absorbing surfaces an impedance similar to that of fiberglass mat was assumed. In this case the parameters used to calculate the surface impedance were effective flow resistivity 6300 $Nsm^{-4}$, porosity 0.9, tortuosity 1.5, pore shape factor 0.5 and layer depth 0.13m.

The insertion loss is defined as

$$IL = SPL_g - SPL_b$$

where $SPL_g$ is the sound pressure level at a given receiver point without the barrier and $SPL_b$ is the sound pressure level at the same point after the barrier has been erected. The insertion loss was calculated at six receiver positions which were at 1.5m and 4.5m above the ground and 20, 40 and 80m from the barrier, and the average found. The average insertion loss for the different barriers is shown in Table 1. The designs are shown in Figure 1 except for design (e) which comprises a plane screen with two vertical panels mounted at a separation of 0.5m on the opposite side of the screen from the train with their upper edges coincident with the upper edge of the screen [6]. The panels are 0.5m deep.

| Average Insertion Loss dB | | |
|---|---|---|
| Barrier Design | Rigid | Absorbing |
| a) Plane Screen | 11.4 | 17.4<br>14.6 (top 0.75m) |
| b) Cranked | | 15.7 |
| c) Curved | 7.1 | 11.8 |
| d) Cantilevered | 13.5 | 16.4 |
| e) Muliple Edges | | 17.9 |

Table 1. Average Insertion Loss for various forms of railway noise barrier.

## 2.2 Experimental Modelling

The experimental modelling was carried out in an anechoic chamber at a scale of 1:20. The detector was a 1/8" microphone which could be positioned remotely at given coordinates with a precision of ± 0.5mm. The air in the chamber was dehumidified to 3%RH and the air temperature was monitored. The track ballast was modelled using graded gravel which was scaled from full scale ballast using a linear factor of $\sqrt{20}$. The ground surface was Formica board which can be consided as rigid. Accurate models of GEC Alsthom Metro-Cammell Mk 4 carriages and Class 91 locomotives were used. The cross section of this rolling stock is similar to that of many other high speed trains. An airjet sound source, or a combination of an airjet and a loudspeaker, were mounted at a single bogie position. The source type was selected to ensure that the signal was at least 10dB above the background level in the chamber at the receiver position furthest from the source. The experimental setup for a multiple edge noise barrier (type (e)) with rigid surfaces is shown in Figure 2.

At each receiver position the sound pressure was sampled 64 times and the mean narrow band spectrum calculated between 1kHz and 80kHz. This corresponds to a spectral range at full scale of 50Hz to 4kHz. The spectrum was normalised by the free field spectrum of the source and the result was combined into 1/3 octave bands. The spectrum was then adjusted for a typical 1/3 octave source spectrum for noise from a high speed train. The broad band sound pressure level from a single stationary bogie at a given receiver position could then be calculated.

Starting from a point opposite the sound source, at 25m (all dimensions full scale) from the nearside rail the SPLs were measured at points along the train. The receiver height was 1.5m. These results are shown in Figure 3a for unobstructed propagation and for a rigid plane screen. The curves are not smooth because of effects related to the carriage joints. A second series of measurements were made with the sound source in the first bogie of the locomotive (see Figure 2). In this case the SPLs at points beyond the front of the train were measured. Results are shown in Figure 3b. Curves fitted to this data which are used in the further stages of the calculations are also shown in Figure 3. For the fitting a relationship of the form

$$SPL = x_1 - x_2 \log_{10}(d/25)$$

was assumed, where $x_1$ and $x_2$ are constants and $d$ is the distance from source to receiver. These results enable the bypass profile for any single bogie to be calculated.

By appropriate combination of a fitted single bogie bypass profile for each bogie on the train it is possible to generate a profile of sound pressure level as a function of time as a train of specified composition and speed passes a point at 25m from the track. This is shown in Figure 4 for an eight carriage train with a speed of 200km/hr. By extrapolation of the results at large distances from the train the $L_{Aeq,1hr}$ for the bypass can also be calculated.

The performance of a noise barrier can be described in terms of the insertion loss in i) the peak level from a single bogie, ii) the peak level of the bypass profile for the whole train, or iii) the $L_{Aeq,1hr}$.

| Barrier Type | Relative Insertion Loss dB | | |
|---|---|---|---|
| | Single Bogie Maximum | Train Bypass Maximum | $L_{Aeq,1hr}$ |
| a) Rigid Plane | 0.0 | 0.0 | 0.0 |
| a) Part Absorbing Plane (top 0.75m) | 7.5 | 7.5 | 7.4 |
| a) Fully Absorbing Plane | 7.7 | 8.0 | 7.9 |
| b) Rigid Cranked | -1.0 | -1.8 | -1.9 |
| b) Part Absorbing Cranked | 3.9 | 4.2 | 4.1 |
| b) Fully Absorbing Cranked | 8.9 | 8.9 | 8.8 |
| d) Rigid Cantilevered | 2.1 | 1.3 | 1.2 |
| d) Absorbing Cantilevered | 7.2 | 7.6 | 7.4 |
| e) Rigid Plane + Multiple Edges | 3.0 | 2.4 | 2.4 |
| e) Part Absorbing Plane + Multiple Edges | 10.0 | 8.9 | 8.7 |

Table 2. Insertion loss relative to that for a 2m rigid plane screen. The barrier shapes are given in Figure 1.

The insertion loss values for a receiver height of 1.5m, at 25m from the nearside rail for a rigid plane screen 2.0m high were 15.6dB for the single bogie, 14.0dB for the peak bypass sound pressure level and 13.9dB for the $L_{Aeq,1hr}$. Table 2 shows the change in the insertion loss relative to this standard case for the different forms of noise barrier which are described in Figure 1.

## 3. DISCUSSION AND CONCLUSIONS

The numerical model described in Section 2.1 is two dimensional. The results are equivalent In three dimensions to those for a coherent line source of sound along the line of the bogies. This may be a reasonable model of rail wheel noise in that there will be some degree of coherence from sound generated by the rails although the primary sound generation regions will be near the rail wheel contact points. Either monopole or dipole emission characteristics can be modelled. It was found that the insertion losses calculated using the dipole source were generally higher than those for the monopole case, but the difference never exceeded 1.0 dB over the range of receiver positions described earlier. Recently numerical solutions based on the 2D BE method have been developed which enable an incoherent line source of sound to be simulated. One difficulty in adopting this model is that the line source is of infinite length which is not true in the practical case. The numerical model was used to generate results for propagation above a grassland surface because of the difficulty in reproducing accurately such surfaces in the experimental model.

The experiments allow 3D propagation and temporal effects to be modelled. In this case the accuracy depends primarily upon the accuracy of modelling of the source directivity and the surface properties. The three insertion loss indicators used to describe the efficiency of the barriers produce similar results.

In every case the inclusion of the sound absorbing material on the face of the barrier improved the performance. This is to be expected since the reflections between the side of the train and the barrier are reduced. The maximum effect was observed for the cranked barrier with an improvement of about 10dB in the experimental insertion loss results for propagation over rigid ground. For the plane screen the insertion loss results for propagation over grass were lower than for rigid ground. This is expected as a result of the extra attenuation of the ground in the unshielded case.

## ACKNOWLEDGEMENTS

The train models were provided by GEC Alsthom Metro-Cammel. The contribution of Dr. S. N. Chandler-Wilde to the development of the numerical model is acknowledged. The work is supported by Grant GR/K73367 from the Engineering and Physical Sciences Research Council.

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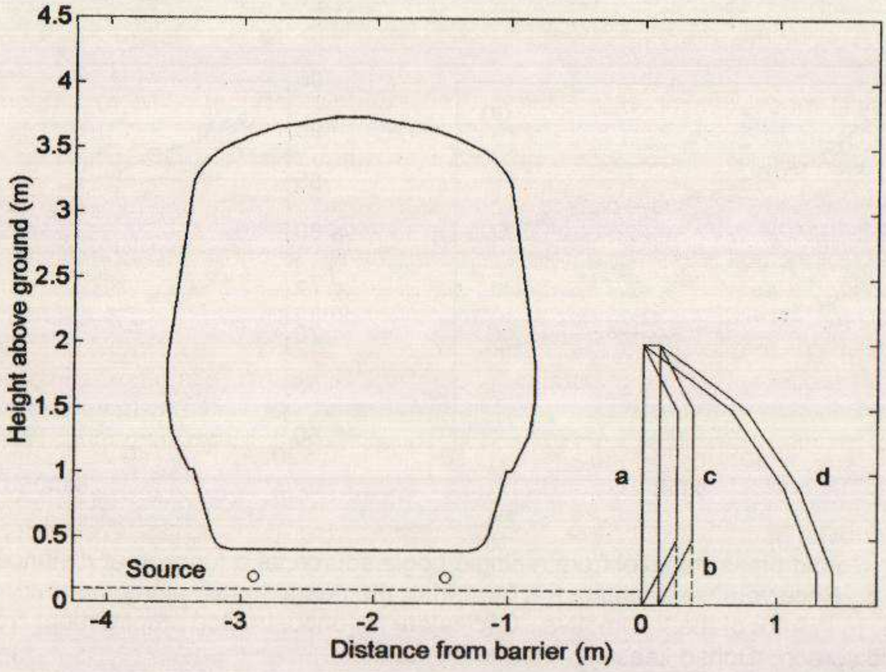


Figure 1. Cross section used in the 2D numerical model. The position and shape of the (a) plane screen, (b) cranked barrier, (c) curved barrier and (d) cantilever barrier are indicated. The position of each of the two dipole sound sources is shown.

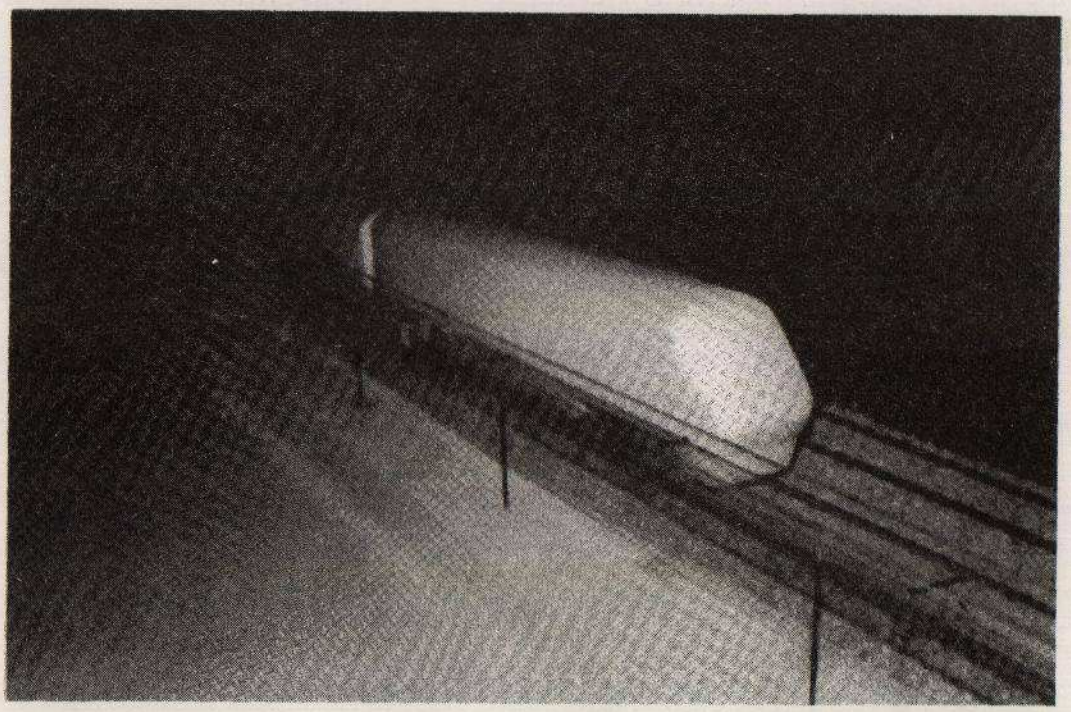

Figure 2. Experimental model. Measurements are being carried out on a multiple edge barrier with rigid surfaces.

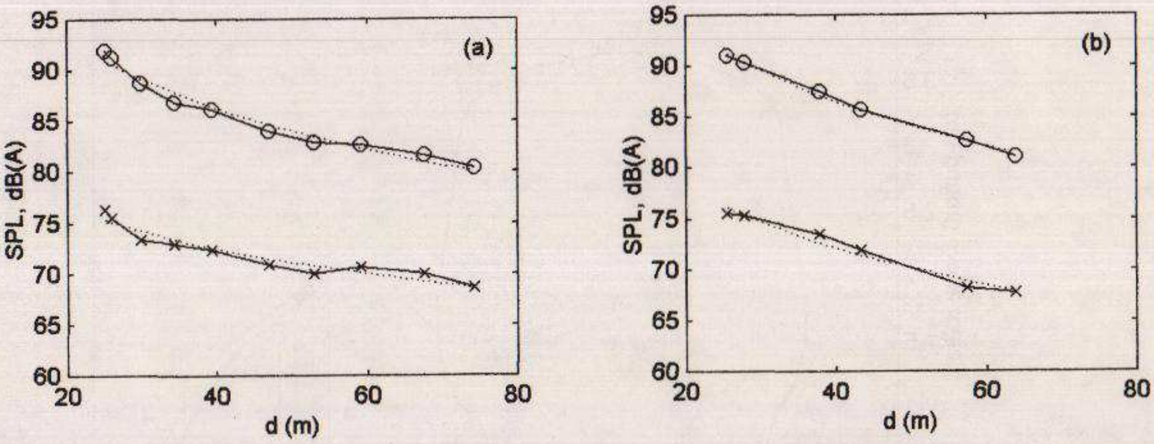


Figure 3. Sound pressure level from a single bogie source as a function of distance from source to receiver, d. Receivers were situated at 25m from the nearside rail, along the train. a) opposite the carriages, b) in front of the locomotive. Circles are for unobstructed propagation; crosses are with a plane rigid screen. Dotted lines are fitted to the data.

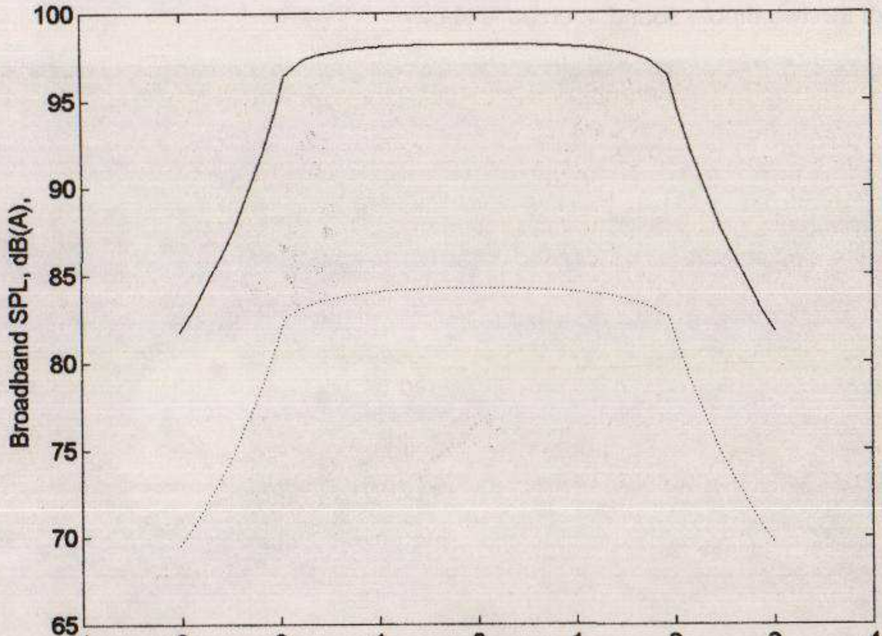


Figure 4. Sound pressure level at 25m from the nearside rail during a train bypass as a function of time. The train speed is 200km/hr. Solid line is for unobstructed propagation; dotted line is with a plane rigid screen at (a) in Figure 1.