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RAILWAY NOISE PROPAGATION CONTROL - AN INVESTIGATION OF RE-RADIATED SOUND FROM VERY LOW TRACKSIDE BARRIERS

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1. INTRODUCTION

A recent research programme, funded by the British Railways Board and Railtrack, has demonstrated experimentally that the control of railway vehicle rolling noise by the application of bogie shrouds combined with very low trackside barriers is acoustically feasible [1]. Typically, shrouds alone can reduce wayside noise by around 5 dB(A) for a train passing at 145 km/h, while the addition of barriers which are 0.25m tall reduces the level by a further 3 dB(A). These barriers have no useful effect, however, on trains without shrouds.

The efficiency of the barriers is dependent on there being minimal clearance between their upper edges and the passing shrouds. This clearance is determined to a great extent by potential suspension movement on the vehicle. It is essential that the barriers be precisely positioned relative to the passing train, to avoid contact with shrouds and other on-board structures whilst maintaining acoustic effectiveness.

It was considered, when designing the original experimental exercise, that the acoustic benefit of low barriers might be negated as a result of re-radiated sound from barrier panels. This situation could arise if sufficiently high levels of vibration were transmitted to the panels from the track structure to generate significant radiated sound. Therefore, the barriers were mounted, during the early tests, through the ballast into the ground as a means of isolating the barriers, to a certain extent, from rails and sleepers. The measured acoustic benefits of this particular system were sufficiently high to indicate that there was no major component of re-radiated sound from the barriers.

Although the experimental barriers remained installed at the BR Test Track at Edwalton for more than a year, long term ballast-mounting of such barriers adjacent to heavily trafficked lines would be unlikely to be practical.

This is because considerable relative movement of track and ballast can occur with time, and the accurate positioning of barriers relative to rails can therefore not be guaranteed over a period. For this reason, it was decided to investigate the potential problem of re-radiated sound from barriers which are directly mounted to the track in order to maintain a precise position relative to the rail. As it was known at the time of the running tests that a system acceptable to railway operators would be likely to have to be mounted in this way, a short length of barrier (4 sleepers) of this type was installed, and its vibration response to the train was measured.

2. THE ANALYTICAL CONCEPT

The method adopted for the current study also involved the installation of a length of sleeper-mounted barrier. In this case, however, the study included the investigation of the barrier's dynamic and acoustic behaviour, and the development of a numerical method to maximise the usefulness of the data obtained. To this end, a low barrier was modelled as a series of identical, acoustically incoherent, sources. Each modelled source consisted of one sleeper attached to an infinite barrier, which is the direct mathematical representation of a configuration which could be realised in practice.

Parameters required as inputs to the numerical model were

(i) transfer functions between vibration input at a single barrier upright and sound at various positions at the trackside, and

(ii) the absolute level of vibration which would have been input at a single barrier upright attached to an infinite barrier, due to the passage of the test train during the running tests.

The latter information would allow a direct comparison to be made between the sound measured from the test train fitted with bogie shrouds, passing between ballast-mounted barriers, and that predicted as being emitted from sleeper-mounted barriers during the passage of the same train.

It was necessary when designing the experimental barrier and the data-gathering exercise to determine the length of barrier which would represent the behaviour of a similar infinite barrier with a single point of excitation at its centre. An important determining factor was the rate of decay of vibration within the structure of the barrier. This was investigated using a 3-dimensional finite element analysis. The analysis showed that vibration input at the centre of the barrier would be sufficiently attenuated to have no significant influence on radiated sound at points 2.5m and greater longitudinally from the centre, over the frequency range of interest, which was 200Hz to 2kHz. The experimental sleeper-mounted barrier had therefore to be at least 5m long.

Measurements of the radiated sound had to be made in the acoustic far field to provide an accurate representation of radiation to the environment. For this reason the microphone was placed at a lateral distance from the barrier of 2.5m.

3. EXPERIMENTAL METHOD

The experimental barrier was installed in untrafficked railway sidings. It consisted of steel uprights clamped to nine adjacent sleepers. These supported a continuous panel of plywood. The barrier was vibrated at a constant level of broad band acceleration at its central point by mounting a vibration exciter horizontally on a pneumatic isolation device.

Two-channel vibration measurement then allowed the transverse acceleration of the barrier to be measured at the central point of excitation and, simultaneously, at a number of other positions on the barrier. This allowed the decay of vibration with distance away from a single excited upright to be quantified. While the constant vibration excitation continued, two-channel sound measurements were taken 2.5m horizontally from the barrier opposite its centre and, simultaneously, opposite each barrier upright along one half of the barrier length. These sound measurements were also taken beyond the end of the barrier, at intervals equivalent to the mean sleeper spacing. Measurement of the cross spectrum between the two microphone positions enabled the effects of background noise to be suppressed. The transfer functions between the vibration of the barrier upright and radiated sound measured at a number of points along the barrier, as required for the model, could then be established.

4. THE MODELLING EXERCISE

The vibration response data from the short length of barrier mounted to 4 sleeper ends during the running tests was used to define the transverse vibration which would exist in each 1/3 octave band at a single upright attached to an infinite barrier as the train passed. This was achieved by applying the following relationship:-

$$A_m = A_t\,[a_0\ /\ a_0] \oplus A_t\,[a_1\ /\ a_0] \oplus A_t\,[a_2\ /\ a_0\ ] \oplus A_t\ [a_{-1}\ /\ a_0\ ]$$

resulting in

$$A_t = A_m/(1 \oplus [a_1\ /\ a_0] \oplus [a_2\ /\ a_0] \oplus [a_{-1}\ /\ a_0])$$

Where: A_m is the measured acceleration level from the earlier experiment

A_t is the transverse acceleration level existing at a single upright attached to an infinite barrier

$[a_n / a_0]$ are the measured vibration transfer functions from the current experiment, between the point of excitation (position n='0') and the adjacent barrier uprights towards both ends of the barrier (positions n=1,2 and -1)

$\oplus$ represents incoherent summation of energy

The sound field in each 1/3 octave band due to all barrier uprights being excited simultaneously by the passage of the test train was then calculated as follows:-

$$L_{ib} = [m_0 / a_0] A_t \oplus [m_1 / a_0] A_t \oplus [m_2 / a_0] A_t \oplus \ldots \oplus [m_{-1} / a_0] A_t \oplus [m_{-2} / a_0] A_t \oplus \ldots$$

Where: L_{ib} is the predicted sound pressure level 2.5m from an infinite barrier

$[m_n / a_0]$ are the transfer functions measured between vibration (a_0) input at the central barrier upright and sound (m_n) measured opposite each barrier upright, 2.5m laterally from the barrier(n=0 is the central position, positive values of n represent uprights to the right of the centre, negative values represent those to the left)

The standard microphone position which was used for the previous full-scale track tests of shrouds and barriers was 12.5m from the nearest rail, 2.2m high. In order for a direct comparison to be made between the new prediction and measurements taken at that time, L_{ib} was corrected by simple geometric considerations to provide a value at the 12.5m measurement position.

The final predicted spectrum thus obtained is shown in Fig 1 as the curve labelled "Prediction". The curve labelled "Measured, shrouded bogies + barrier" shows the spectrum of sound measured 12.5m from the track during the passage of the test train fitted with bogie shrouds travelling at 145 km/h between ballast-mounted barriers. This specific pass-by was the event which also provided vibration data from the barrier attached to 4 sleepers which has been used as an input for all subsequent predictions.

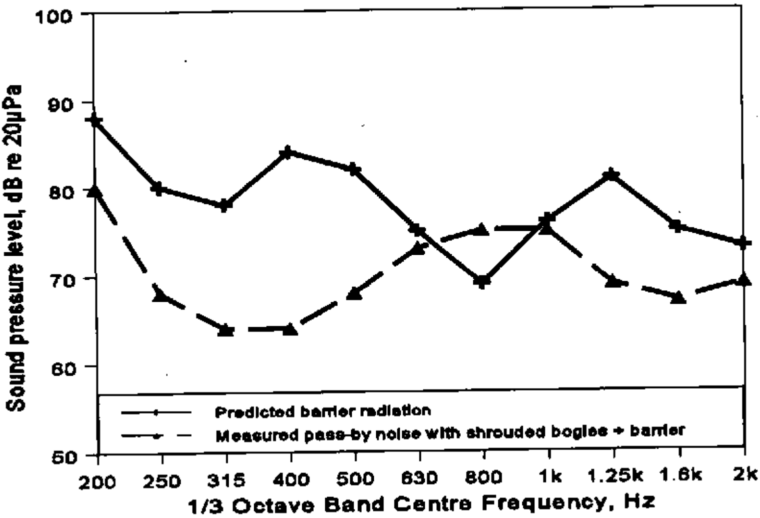

Fig. 1. Prediction of re-radiated sound from an infinite low barrier, measured at a position 12.5m from the nearest rail, 2.2m high, for a train fitted with bogie shrouds passing at 145 km/h

5. DISCUSSION OF RESULTS

The figure shows that the modelled infinite sleeper-mounted barrier will radiate sound energy, at frequencies below 630Hz and above 1kHz, which is considerably in excess of that measured when shrouded bogies pass between ballast-mounted barriers. This bears out the findings of an earlier preliminary 2-dimensional boundary element modelling exercise which used the same vibration input data. The implication of the results is that the sleeper-mounting of low barriers may not be acoustically acceptable without the incorporation of techniques for reducing vibration transmitted to the barriers, or of methods for decreasing their radiation efficiency.

Techniques which have been considered include the insertion of resilient elements into the barrier support structure, the stiffening of the support brackets, tuned dynamic absorbers, and constrained layer damping on the barrier panel. 2-dimensional finite element modelling of the various techniques has shown that a combination of all these approaches may not be sufficient to overcome the problem. Further, more radical, solutions are therefore currently under consideration.

6. CONCLUSIONS

The control of railway rolling noise by means of bogie shrouds and low barriers, as developed by BR Research, has been shown to be acoustically feasible provided the barriers can be isolated from the track structure. A modelling exercise has been carried out utilising empirically-derived data from two short lengths of barrier, one excited by a test train and the other excited in a controlled fashion by a vibrator. This exercise has shown that mechanical coupling of the barrier to the sleepers is likely to lead to levels of re-radiated sound which can negate any beneficial effect of the shrouds and barriers. Further examination of techniques to overcome this problem will be required before low barriers can be considered for reliable long term installation.

7. REFERENCE

[1] R.R.K.Jones, 'Railway Noise Control Using Combined Vehicle and Track Treatments', World Congress on Railway Research, Paris, 1994.

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