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USING A BOUNDARY ELEMENT APPROACH TO STUDY SMALL SCREENS CLOSE TO RAILS

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A boundary element program based on a variational approach is used to study the efficiency of small screens placed very close to the rails, in addition to a normal full-size noise barrier. Seven dipoles represent the noise generated by the sleepers, the wheels and the rails. In order to reduce the noise emitted by these sources the screens must be absorbent. Further noise reduction is achieved by adding some absorbing material under the car.

1. INTRODUCTION

The study of noise barriers close to railways involves complex phenomena combining acoustic reflections between the train and the barriers as well as diffraction effects. In order to optimize the barriers, numerical simulations can be used, provided that the solution is precise and can be obtained at a reasonable cost for the full audio-frequency range. The use of boundary element methods is well suited to this situation, if applied in 2-D and assuming a geometry of infinite extent in one direction. Such an assumption greatly reduces the number of unknowns, since simple contours will then be discretized and consequently solutions may be calculated up to 5000 Hz.

The computer program MICADO [1, 2] based on boundary elements and a variational approach has been applied to the case of small screens placed closed to the rails under a train. These screens, which project only a few centimeters above the rail head, are in addition to a normal full-size noise barrier. The effect of adding some mineral wool under the cars is also considered.

2. THE NUMERICAL MODEL

A boundary element formalism has been adopted and is fully described in reference [1]. A 2-D geometry is considered with a classical harmonic dependence. The ground is assumed to be flat, of infinite extent and can be either rigid or of constant admittance α at a given frequency. The Green function includes the ground effect [3], and the integral representation is therefore limited to all

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boundaries S differing from the infinite reference ground. These boundaries, to be discretized, are either above ground or on the ground with admittances Y different from α. Y may vary with position along the boundaries. The integral representation of the pressure is not used in a straightforward manner as is the case in collocation approaches [3]. Instead, it is further processed into a functional, the minimum of which leads to the solution. This functional is obtained as an integral over the boundaries S for a combined expression of the pressure and its derivative with regard to the normal to S. Therefore, the matrix is obtained as a discretization of double integrals over S. This matrix is symmetrical, thus reducing the resolution time.

The discretization is made with linear two-node elements, and since the boundaries are simple contours, it is easy to perform adaptive meshing by defining the boundaries S as sets of segments divided into elements small enough with respect to the acoustic wavelength. Typically, five elements per wavelength is sufficient. It should also be noted that the problem of irregular frequencies is not major and irregular results are almost non-existent, provided that precise meshing is used [2]. After solving the matrix system the pressure is obtained at any point by using the discretized version of the original integral representation. The computer program has been named MICADO which stands in French for “Méthode Intégrale de Calcul Acoustique de la Diffraction par les Obstacles”.

3. APPLICATION TO SMALL SCREENS CLOSE TO TRAINS

The case of small screens placed near the rails is considered. Figure 1 shows a view of the 2-D profile of the bodywork of a train above ballast, a vertical straight barrier, 2·15 m high and 4·5 m away from the track centreline, with mineral wool facing the train (flow resistivity of $\sigma = 30\ \mathrm{kN\,s/m^4}$ and thickness = 5 cm in the Delany and Bazley model [4]). Two small screens are placed near the rails; they are 2 cm thick and they are positioned 87 cm away from the track centreline; they project 55, 105 or 155 mm above the rails head. The ballast is modelled with $\sigma = 300\ \mathrm{kN\,s/m^4}$ and infinite thickness. The ground is rigid elsewhere.

The noise radiated by the lower part of the train is modelled with seven incoherent dipoles: three vertical dipoles for the sleeper (E_1), the right (E_2) and the left (E_5) rails and four horizontal dipoles for the right (E_3) and the left (E_6) rails and the right (E_4) and the left (E_7) wheels. In the case of a Corail wheel on a UIC60 rail on bibloc concrete sleepers, Figure 2 gives the separate contributions of these sources, as given by the European Rail Research Institute with the help of the TWINS model; letters V and H stand for vertical and horizontal dipoles respectively. The sources are assumed to be totally incoherent. Therefore, each problem is solved seven times and the sound power levels are summed in energy at all points of interest. It should be noted that this does not involve a multiplication of the total computation time by a factor of seven, since the resolution algorithm, based on a Cholevsky decomposition, stores an intermediate decomposition of the matrix once for all. The back-substitution part of the resolution, which is different for the various sources, takes a minor part of the total resolution time.

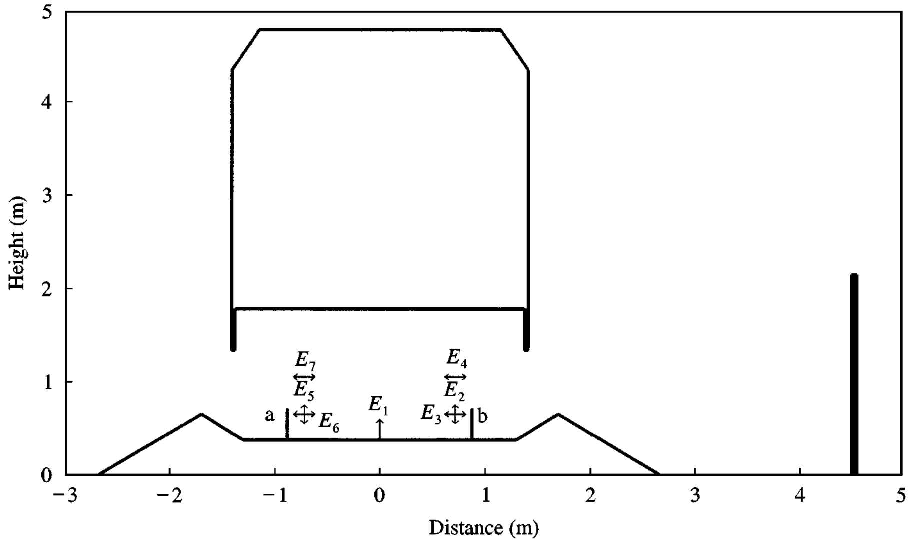

Figure 1. Geometry of train, ballast, screens (a, b), sources (dipoles 1–7) and barrier.

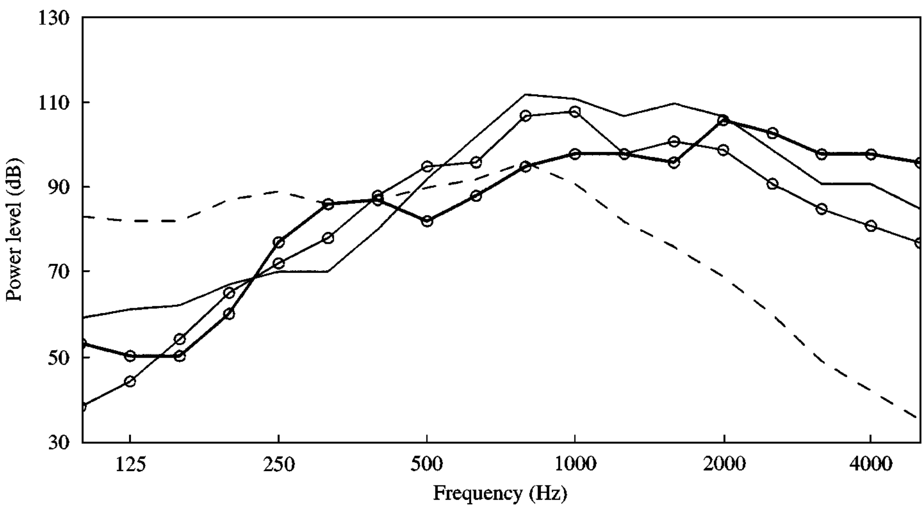

Figure 2. Separate powers of dipole sources. —, Sleeper V; - - -, rail V; ○—○ rail H; ○—○, wheel H.

Consequently, dealing with seven sources only adds a few percent of computation time compared to the case with only one source, provided that only a few pressure points are wanted.

Nine receiving points are considered at 20, 45 and 95 m behind the screen. Three different heights are used for every distance such that one is deep in a shadow zone of the noise barrier (M_1, M_4, M_7) one is in the transition zone (M_2, M_5, M_8) and one is in direct view from the sources (M_3, M_6, M_9). The exact positions with respect to Figure 1 are given in Table 1.

TABLE 1

Efficiency in dB (A) *of small screens placed near the rails. Three heights of screens*: 55, 105, 155 mm *above the rail head*

Receivers Position distance/height (m)		M_1 25/5·65	M_2 25/10	M_3 25/14	M_4 50/5·65	M_5 50/20	M_6 50/26	M_7 100/5·65	M_8 100/40	M_9 100/50
Hard screens	55 mm	−0·4	−0·3	+0·6	−0·2	−0·4	+0·3	0	−0·4	+0·1
	105 mm	−0·5	−0·1	+1·2	−0·1	−0·1	+0·7	+0·1	−0·2	+0·6
	155 mm	−0·7	0	+1·5	−0·1	0	+1·0	−0·1	0	+0·7
Absorbent screens	55 mm	+1·2	+1·5	+2·4	+1·3	+1·3	+2·0	+1·6	+1·3	+1·9
	105 mm	+1·8	+2·3	+3·6	+1·9	+2·1	+3·0	+2·3	+2·1	+2·8
	155 mm	+2·3	+3·0	+4·7	+2·6	+2·8	+4·0	+2·8	+2·9	+3·7
+ wool under car	55 mm	+2·0	+2·5	+3·4	+2·3	+2·2	+3·0	+2·2	+2·2	+2·8
	105 mm	+2·6	+3·3	+4·7	+2·8	+2·1	+2·2	+2·2	+2·2	+2·8
	155 mm	+3·1	+4·0	+6·0	+3·4	+3·0	+5·2	+3·7	+3·9	+4·9

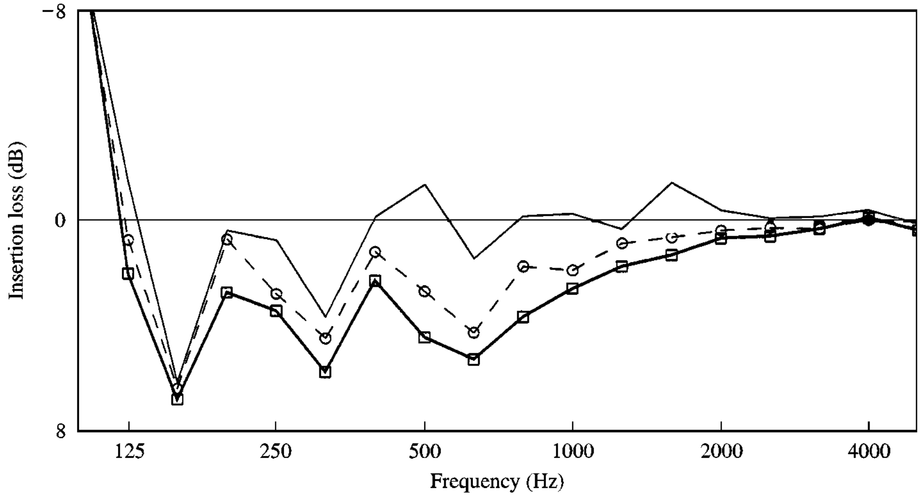

Figure 3. Insertion loss of the small screens at M1 (25, 5·65). —, Rigid screens; ○—○, absorbing screens; □—□ absorbing screens + mineral wool under car. Negative values means an increase in sound level at this receiver position.

Three situations are considered: (a) the small screens are rigid, (b) the same screens are covered with 5 cm of mineral wool, (c) as (b) but in addition to the screens, the same mineral wool is placed under the car. Table 1 summarizes the reduction levels in dB (A) for the nine receiving positions in the three situations, for the three screen heights. Positive results, indicate that a global reduction of noise due to the presence of the small screens can be found at all points when the small screens are treated. For the rigid screens, only the highest points (M_3, M_6, M_9) in direct view from the train receive less noise. Even for absorbing screens, the best attenuation is obtained at these highest points. Overall, these results show that between 1 and 4 dB (A) noise reduction can be expected by using small screens in addition to the large noise barriers. The addition of mineral wool under the car gives about 1 dB (A) improvement at all points and for the three heights of screens.

Figures 3 and 4 represent the noise-reduction spectrum due to the smallest screens (+55 mm above rail head) at point M_1 (25 m behind screen and 5·65 m above ground). Figure 3 correspond to the seven dipoles activated simultaneously, whereas Figure 4 shows the separate contribution for each dipole. In each graph, the three plots correspond to the three situations (a)–(c).

Figure 3 shows that at 100 Hz, the small screens degrade the results, even if they are treated. This is due to the interaction of the vertical dipoles with the small screens. This means that the dipole horizontal minimum pressure field is replaced by a maximum, resulting in an increase of energy radiated in this direction. The detailed analysis of Figure 4 confirms that the vertical dipoles E_1, E_2 and E_5 are most affected by this low-frequency effect. The horizontal dipole E_3, representing part of the the right rail noise, is the dipole which is reduced most efficiently by the screens especially when they are treated, whereas the top E_4 and E_7 horizontal

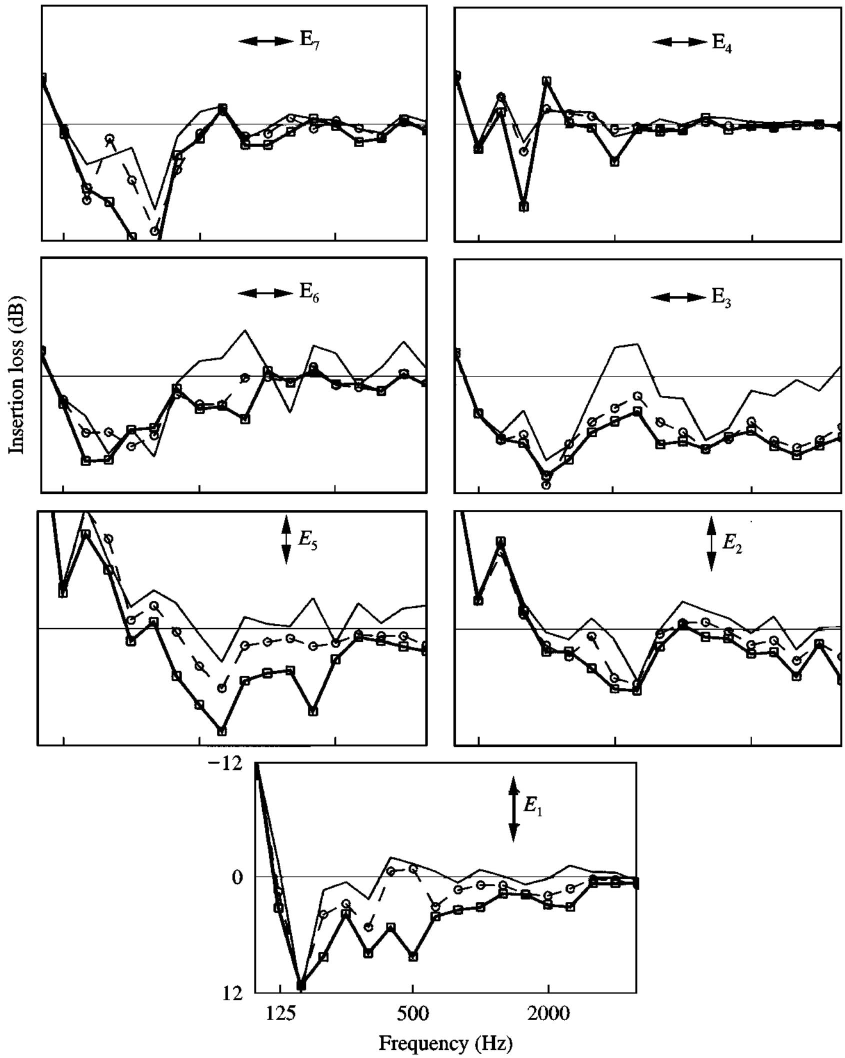

Figure 4. Insertion loss of the small screens at point M1 for individual sources. —, Rigid screens; ○—○ absorbing screens; □—□ absorbing screens + mineral wool under car.

dipoles (for the wheels) positioned above the screens are the least affected. The positive effect of the mineral wool on the small screens appears clearly in Figures 3 and 4 with a positive efficiency for the largest part of the spectrum. The addition of absorbing material under the car further enhances these effects.

The same calculations have also been carried out without the normal full-size noise barriers. Generally speaking, the reduction caused by the small screens alone is similar to the reduction with a full-size barrier reported in Table 1. At points M_4 and M_7, 5·65 m above ground, in the case of absorbent small screens and no treatment under the car, these values may be reduced by more than 1 dB. If the underside of the car is treated, again except at points M_4 and M_7, the efficiency of the small screens may increase by 1 or 2 dB (A) if the full-size barrier is not included.

5. CONCLUSION

The use of a 2-D boundary element method is well suited to the study of noise barriers close to trains. The model should be as close as possible to reality; the ground absorption, the interaction between train and barriers as well as any close distance effects are of prime importance. The program can be used to study innovative solutions such as the introduction of small absorbent screens close to the rails. This solution leads to a noise reduction of approximately 2–3 dB (A). Adding absorbent material under the car body can reduce the emitted noise levels by a further 1 dB (A).

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