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Evaluating the Effectiveness of Novel Noise Barrier Designs

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In recent years there has been growing interest in the use of noise barrier profiles that can enhance the diffraction efficiency of plane barriers. These are placed on the top of the barrier in order to reduce sound diffracted into the shadow zone. Despite numerous demonstrations that the profiles enhance performance there is as yet no universal agreement on how the improvements can be quantified and incorporated into revised current noise prediction methods or proposed methods such as Harmonoise. Without such quantification it is unlikely that such profiles will receive widespread acceptance. TRL has carried out an experimental investigation of the performance of novel shaped barriers for the Transport Research Foundation. The approach relies on quantifying diffraction efficiency in the near-field using a novel application of the maximum length sequence (MLS)-based method. The method clearly revealed a difference in the performance of the options tested and result agreed well with numerical predictions using the boundary element method (BEM).

1. INTRODUCTION

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In recent years there has been considerable interest in designing barrier profiles that improve on the screening performance provided by a simple thin screen of the same overall height. Such add-on devices can take a variety of forms including multiple-edge profiles, absorptive T-shapes and rounded caps. To encourage the use of these innovative barrier profiles there is a need to characterise their acoustic performance under a wide range of conditions. The advantages can then more easily be taken into account in revising current noise prediction models or in proposed methods such as Harmonoise, which is currently being developed for use in EU countries [1].

The European Standards Group CEN TC 226/WG6 have developed draft standards on measuring in-situ absorption and transmission loss of noise barriers [2] and are examining methods for diffraction. This paper describes an investigation of the performance of capped barriers using a novel application of the Maximum Length Sequence (MLS)-based method [3] to characterise diffraction efficiency. The main advantage of this approach is that measurements can be taken in-situ in the presence of high extraneous noise, e.g. at the edge of a busy motorway. For the purpose of this study, however, the measurements were carried out at TRL's experimental noise barrier facility.

2. THEORY

The basic geometry for characterising the diffraction efficiency of a noise barrier is shown in Figure 1. For the measurement of the efficiency of devices added to the top of a noise barrier, measurements must first be performed in the absence of the device. It should be noted that the microphone is not located in the deep shadow zone below the top of the barrier. This ensures that the diffracted component of the impulse response will be considerably greater in magnitude than any transmitted components. The diffracted component can then be extracted using the temporal separation principle. Using a similar separation between source and receiver the measurement is repeated under free-field conditions. The ratio between the diffracted and free-field responses provides a measure of attenuation provided by the added device.

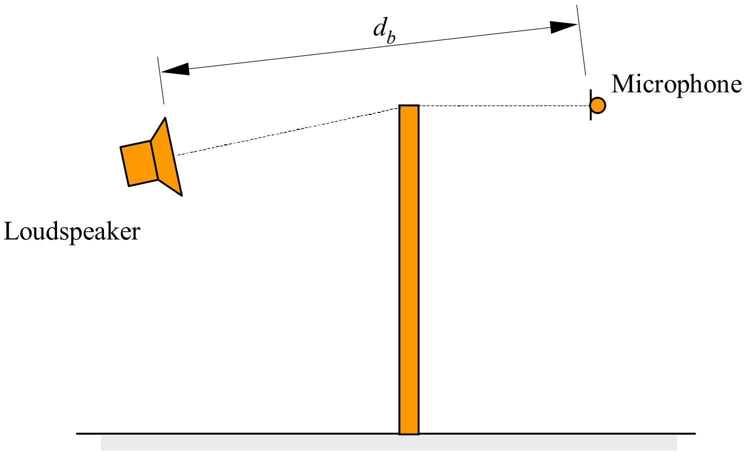


Figure 1. *Test arrangement for characterising the diffraction efficiency of a noise barrier*

The formula for calculating the insertion loss (the level difference with and without a barrier present) is given by

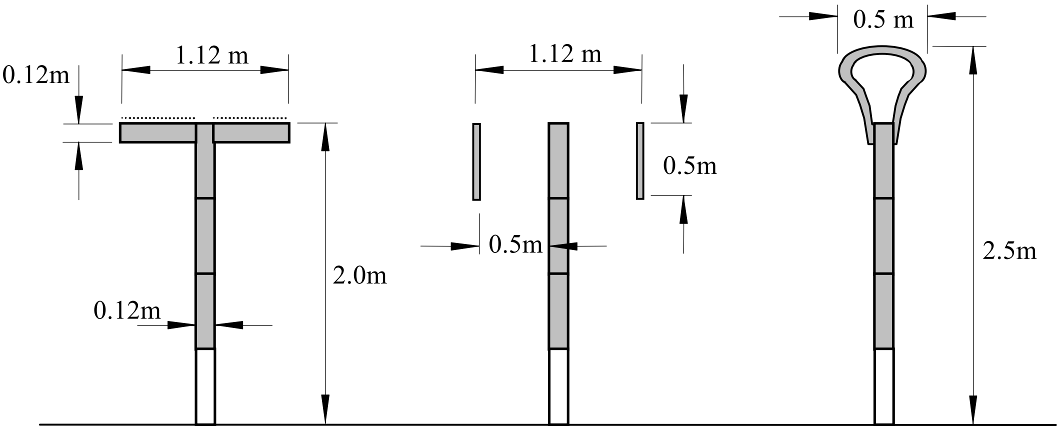
$$IL(f) = -10 \times \log_{10}\left\{\frac{|H_b(f)|}{|H_i(f)|} \times \frac{d_b}{d_i}\right\}^2 \text{ dB} \tag{1}$$

where $H_b(f)$ is the frequency response of the diffracted component impulse response, $H_i(f)$ is the frequency response of the free-field impulse response and, d_b and d_i are the lengths of the shortest direct path though the barrier and the free-field path respectively.

3. BARRIER PROFILES INVESTIGATED

The cross-sectional designs of the different novel barriers investigated, together with appropriate dimensions, are shown in Figures 2 and 3. For each barrier the main upright was 2.0 m high, 5.0 m long, 0.12 m thick and formed from 2 bays. Each bay was comprised of a 0.5 m high plane concrete plinth at the base and three aluminium box-section panels (dimensions 2.5 × 0.5 × 0.12 m) held in place between vertical I-section steel beams. All these surfaces were acoustically reflective. The sound insulation value of the barrier was high, being over 40 dB at 1000 Hz.

For the T-shaped barrier the panels used incorporated a sound absorptive face on one side and a reflective face on the other. The absorptive face was formed from a perforated facing and a rockwool material. This resulted in this side of the panel having a mean absorption coefficient of $\alpha > 0.8$ (over the frequency range 0.25 – 5.0 kHz). The other side of the panel was constructed from un-perforated aluminium sheet and was therefore highly reflective. To create the absorptive T-shape profile the absorptive face was placed uppermost, whilst to create a reflective T-shape, the panels were turned so that the reflective face was uppermost. The multiple-edge barrier consisted of two additional side panels, attached parallel to the main upright, one on either side



Profile (a) Profile (b) Profile (c)

Figure 2. *Test barrier profiles: (a) T-shaped barrier; (b) multiple-edge profile; (c) absorptive rounded cap*

(separation = 0.5 m), using light structural steel beams attached to the main posts to produce a design symmetrical about the vertical axis. The panels, constructed from thin sheet steel, were 0.5 m high and positioned with the upper edge flush with the top of the main barrier. This original concept of this design i.e. multiple diffracting edges on a single foundation, was jointly invented and optimised by TRL and the University of Bradford [4]. Patents were successfully applied for and the design tested at motorway sites [5]. The rounded cap fitted to the plane barrier was a commercial product, and consisted of a curved perforated polycarbonate sheet that enveloped a 50 mm thick layer of mineral wool. The absorption properties of the cap were not specified.

The overall set-up was therefore novel in that the performance of new designs of barrier profile could be investigated at full scale, outside and in the presence of non-homogeneous atmospheres. In this way the experimental conditions were capable of representing the roadside situation.

4. MEASUREMENT METHOD

A loudspeaker source and microphone were placed on opposite sides of the barrier under test and set at different heights for different inclinations in the vertical plane. All measurements were performed with the loudspeaker and receiver microphone axis perpendicular to the top edge of the barrier, i.e. normal incidence in the horizontal plane. Two source positions and four microphone positions were used for each barrier configuration, resulting in 8 measurement combinations per configuration. For all of the barrier configurations, the same source/receiver heights were applied relative to the leading/trailing diffracting edges of the barriers, resulting in constant angles of inclination. The horizontal separation between the barrier and these source/receiver positions was set at 1.0 m from the position of the leading/trailing diffracting edges respectively. These positions are illustrated in Figure 3 relative to the multiple-edge barrier. For the barrier with the rounded cap, the position of the diffracting edge was defined as the tangent point for the line of sight from any source or receiver position. Consequently, the lower sources and receivers were further from the barrier centre than for any of the other options. The orientation of the selected sources corresponded to the angles that would be defined by a 3m

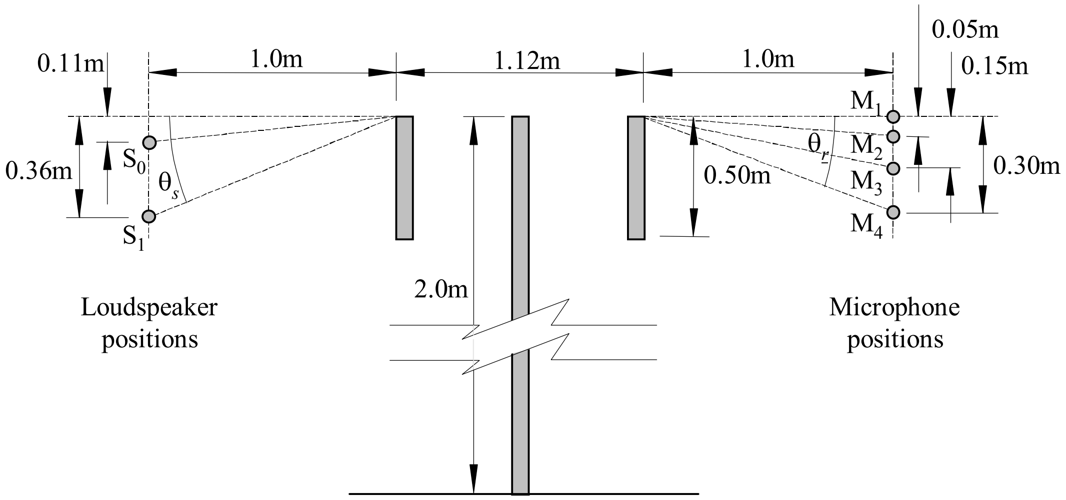


Figure 3. *Positions of source and microphone relative to a multiple-edge profile*

high barrier were the sources to be located in the middle of the nearside and farside carriageways of a motorway (S_1 and S_0 respectively). The orientation of the receiver positions corresponded to the angles which would be defined by the head of a standing adult at distances of 30, 10 and 5 m from the 3m high barrier (M_2, M_3 and M_4 respectively). The receiver horizontal with the barrier top (M_1) would of course be at a large distance from the barrier.

5. RESULTS

The insertion losses normalised to zero wind speed were plotted against frequency for each option tested. Figure 4a and Figure 4b show the results for 2 measurement positions (the microphone level with the top of the barrier and source positions 0.11 m and 0.36 m below the top). The results indicate the main tendencies shown in the full set of results that have been analysed for all 8 measurement geometries, i.e. 2 source positions and 4 microphone positions.

Generally for all options there is a rise of insertion loss with increasing frequency. At the lowest frequency the insertion losses are comparable, but diverge as the frequency increases. At most frequencies the absorptive T-shape produces the greatest insertion loss and the cylinder and plane barrier the least. The largest differences are close to 15 dB(A). At the three lowest frequencies the multiple-edge profile produced the largest insertion loss while at 850Hz and above the absorptive T-shape produced the largest effect. The performance of the reflective T-shape option tends to be intermediate lying between that of the multiple-edge and that of the plane and cylinder options.

Comparisons were made between the measured values of insertion loss and those calculated using a 2-D boundary element method (BEM) [6]. The effects of the ground plane were effectively removed by modelling a 10m high barrier, but keeping the positions of the microphones and sources relative to the barrier profile identical to those in the test measurements. BEM predictions were made for all of the barrier options except the barrier with

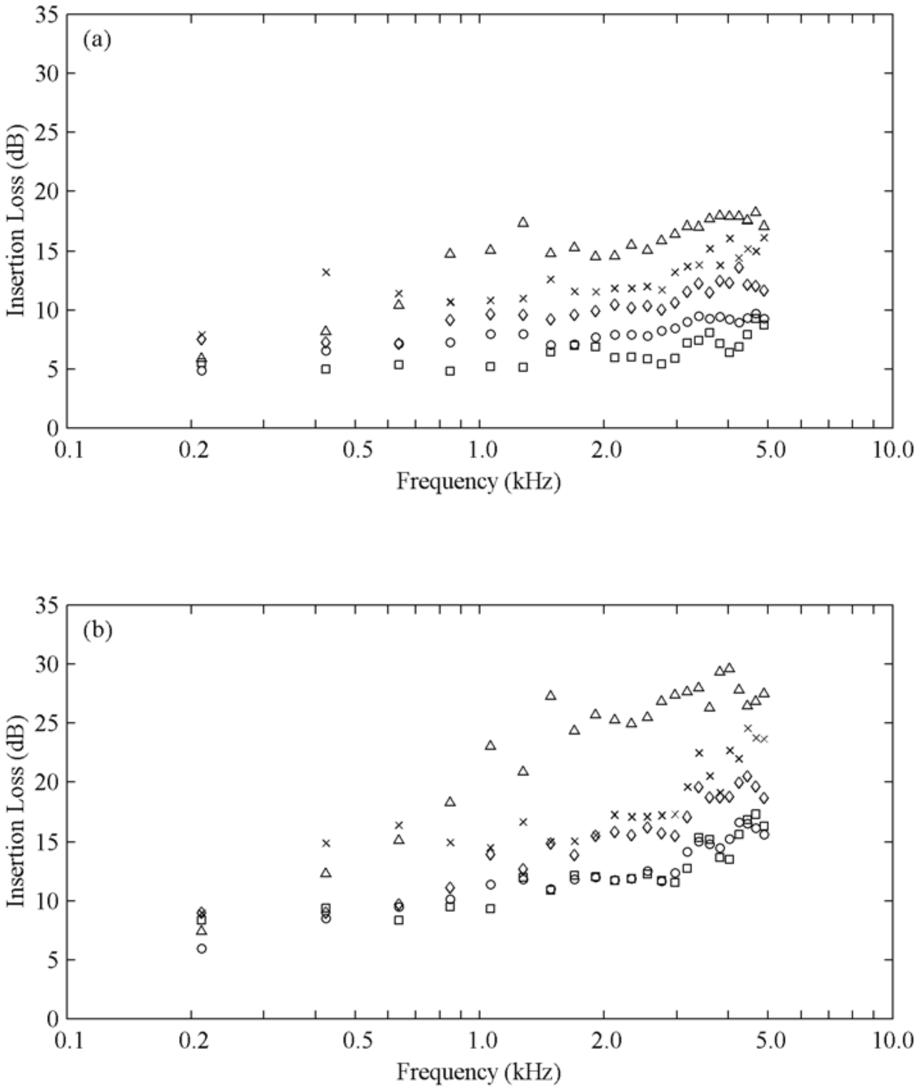


Figure 4. *Insertion loss spectra for receiver level with profile top (a) for source at 0.11m below profile top and (b) for source 0.36m below profile top. (○) plane barrier, (□) rounded cap, (◇) reflective T-profile, (△) absorptive T-profile, (×) multiple-edge barrier*

the rounded cap for which values of absorption were not available. The frequencies chosen were identical to those for which measurement data was available except that at high frequencies predictions were only made for frequencies closest to third octave band centres. Figure 5 gives the results for the multiple-edge profiles with the receiver level with the barrier top and for the source 0.11cm below the profile barrier top.

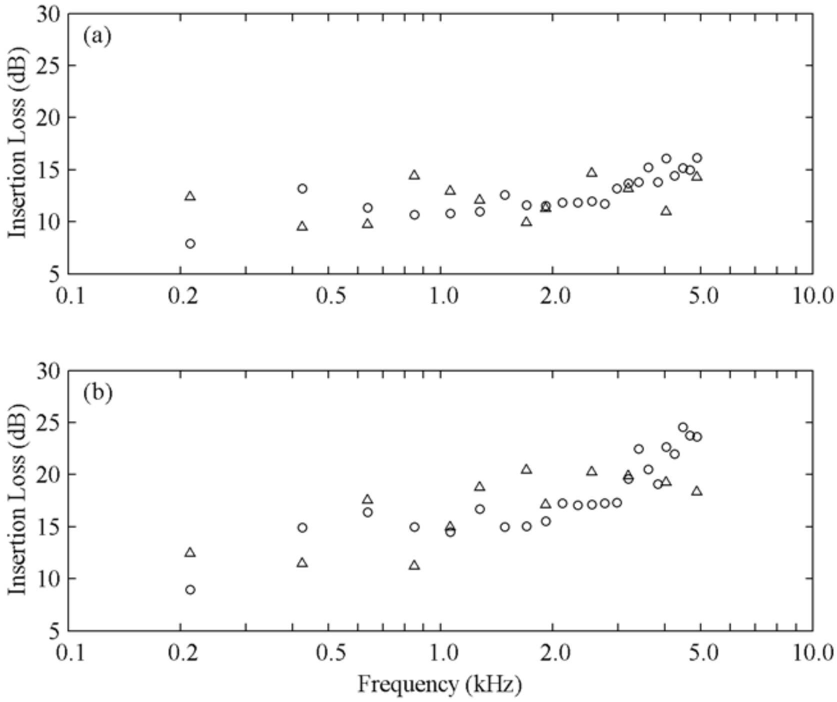


Figure 5. *Insertion loss spectra for multiple-edge barrier with receiver level with profile top (a) for source at 0.11m below profile top and (b) for source 0.36m below profile top. (○) measured, (△) BEM prediction*

6. CONCLUSIONS

Across all options examined there is generally good agreement within ±5 dB between the measured and predicted spectra, and the data lends support to the validity of the new measurement method for quantifying barrier profiles. Using the measured results it should be possible to calibrate the input to the BEM in order to produce even closer agreement. Such a calibrated model could be used within noise prediction methods such as Harmonoise to determine performance in the far field for use by highway authorities providing noise mitigation.

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