Applied Acoustics 96 (2015) 139–152

Contents lists available at ScienceDirect

Applied Acoustics

journal homepage: www.elsevier.com/locate/apacoust

A parametric investigation of the performance of multiple edge highway noise barriers and proposals for design guidance

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ARTICLE INFO

Article history:
Received 25 August 2014
Received in revised form 10 March 2015
Accepted 19 March 2015
Available online 22 April 2015

Keywords:
Multi-edged barriers
Boundary Element Method
Additional edges
Traffic noise
Design proposals

ABSTRACT

The Boundary Element Method has been employed for a parametric investigation of the performance afforded by highway noise barriers with multi-edge tops and different acoustic treatment. Configurations investigated included single additional edges located on either the source or receiver sides of the barrier and two additional edges located symmetrically on each side of the barrier. The effect of treating the internal faces with a sound absorbing material was also investigated. The parameters investigated included the source to barrier distance, the receiver to barrier distance, the barrier height, the length of the additional edge and the gap between the additional edges and the face of the barrier. The values of each parameter were selected to be those appropriate to a practical installation. The performance of each edge variation was investigated for both reflective and absorptive faces. The relative insertion loss afforded by a given multi-edge configuration was found to be a function of the location of the source, the barrier and the receiver and also the height of the barrier. However, the sensitivity of the relative insertion loss to variations in most parameters was not great. For both reflective and absorptive treatments, the relative insertion loss of most additional edges was found to be only slightly greater on increasing the length of the edge above 0.5 m. Although there was always an increase with increasing gap width over the range of widths investigated gap but the indications were that benefit to be obtained for gap widths in excess of 0.4 m may not be an economic proposition. For source locations close to the barrier and receiver locations in the far field, as would be appropriate for a highway noise barrier, although the relative insertion loss afforded by a reflective additional edge located on the source side of the barrier is generally low, significant attenuation can be obtained when an absorptive treatment with a high coefficient of absorption at frequencies around 1000 Hz is applied to the device. However, a reflective edge located on the source side of a barrier at very short source to barrier distances and/or high barriers was found to result in a negative value of relative insertion loss and an explanation based upon resonances in the gap between the additional edge and the barrier was postulated. The use of two additional edges located symmetrically either side of a barrier can be a very effective means of improving the performance of a highway noise barrier giving relative insertion loss values that are high and consistent over a large range of parameters for both reflective and absorptive surfaces. However, in the former case the performance can be severely reduced for combinations of short source to barrier distances and/or high barriers.

1. Introduction

Following from the early work of May and Osman [1], various attempts have been made to achieve improved performance for a barrier of a given height by modifications such as the use of additional diffracting edges and/or the use of impedance devices located on the top edge. The improvement in performance is usually expressed in terms of a relative insertion loss which is the additional attenuation achieved relative to that of a simple barrier of the same height. In a companion paper the authors have presented the results of a comprehensive investigation of the effect of different parameters on the performance of a T-profiled noise barrier and demonstrated that this varies systematically with the geometrical configuration [2]. The results of this investigation were used to propose a potential predictive method for this barrier configuration. However, although the T-profile barrier top, when treated with sound absorbent material, can offer significant

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http://dx.doi.org/10.1016/j.apacoust.2015.03.012
0003-682X/

additional attenuation, the large width of top required to achieve a reasonable increase in relative insertion loss imposes structural and wind loading problems. In addition, the positioning of porous material on a horizontal surface exposed to rain, sun, dust and atmospheric pollution raises problems of durability that have tended to mitigate against the adoption of the T-profile as a practical solution.

Recent work has tended to be concentrated on more complex devices such as the use of Quadratic Residue Diffusers [3,4], on the optimisation of multi-edge barriers and T-tops [5,6] and also the basic shapes of noise barriers [7]. However, in this paper we examine the performance of additional vertical edges located at the top of a barrier which is simple to manufacture as the T-profile but less at risk from problems due to rain, sun, dust and wind loading. The relative ease of manufacture and hence potentially low cost of simple devices such as the use of additional vertical edges means that they remain worthy of further investigation. As pointed out by Crombie et al. [8] and Watts [9], the use of additional vertical edges is particularly attractive as they have the potential to be retrofitted to existing barriers with minimal structural difficulty.

Although much of the earlier work on such devices was of a high standard, the results presented by different investigators were frequently conflicting and thus cannot be used with confidence by highway engineers seeking to predict the benefit to be gained from employing them. ISO 9613-2:1996 contains a procedure for calculating the effect of double diffraction, however, it is intended for application to wide or double barriers rather than additional edges [10]. In addition, Parzych [11] has reported that application of this standard to noise barriers is potentially confusing and gives no intuitive insight to the user.

The first objective of this work was to conduct a parametric investigation of factors affecting the acoustical performance of multi-edge highway noise barriers with a view to clarifying the existing situation. A detailed study was undertaken using computer modelling of the effect on its acoustical performance of changing the values of various parameters of the simple multi-edge barrier. The second objective was to examine the data obtained from this parametric investigation in order to identify design guidance to aid the highway engineer in the selection of the most appropriate configuration for a given situation.

A preliminary investigation was undertaken to investigate the effect of source location and barrier height on the performance of a small number of multi-edge configurations in order to establish a suitable range of configuration for a more detailed study. A parametric study was then carried out of the performance of 135 different configurations of multi-edge barriers. Finally, the results of the study were examined and used to extract design guidance.

2. Previous work on multi-edge barrier tops

The most significant early work on multi-edge barriers was carried out by Crombie et al. [8,12] who employed the Boundary Element Method (BEM) to examine a large number of profiles. Parameters varied included the height of side pieces, typically in the range 0.5–2 m, and the separation of the side pieces from the main barrier wall, typically 0.5–1 m. They considered single side pieces (on both source and receiver sides of the barrier), single side pieces either side of the barrier, and multiple side pieces, of equal or different lengths and either on one side of the barrier or arranged symmetrically on either side. They also investigated the performance when the surfaces of the main barrier wall were treated with absorptive material. The increase in relative insertion loss was expressed as a single figure value based upon a traffic noise spectrum modified by the barrier attenuation and as the mean value calculated at receiver positions 20, 50 and 100 m from the barrier. They obtained a range of relative insertion loss values from 0.4 dBA, corresponding to the simplest case of a 0.5 m high side piece located on the source side and 1 m from the main barrier wall, to 4.9 dBA, corresponding to the more complex case of two lots of three side pieces of different lengths arranged 0.5 m apart and positioned symmetrically either side of an absorbent main barrier wall.

Watts et al. [13] have reported full scale tests carried out to measure the acoustical performance of a number of top edge configurations. For symmetric multiple edge configurations with side pieces 0.5 m high and situated 0.5 m either side of the main barrier wall they obtained a relative insertion loss of 2.4 dBA with the barrier face reflective and 2.5 dBA with the top 0.5 m of the barrier absorptive. Relative insertion losses of 2.6 dBA and 2.7 dBA were determined for side pieces 1 m high and located 0.5 m either side of the absorptive barrier top and 0.5 m high located 1 m either side of the absorptive barrier top respectively.

Watts has carried out a series of measurements on a multiple edge configuration retro fitted to an existing roadside barrier [9]. However, the results obtained were affected by the normal problems associated with attempting to measure small level differences in field conditions but indicated potential performance gains of the order of 2 dBA for reflective multi-edge barrier configurations.

Ishizuka and Fujiwara [14] have presented results for two additional edges where the distance of each panel from the main barrier wall was 0.5 m and their heights were both 0.5 m. They reported an increase in relative insertion loss of 0.2 dBA. Crombie et al. do not present data for an identical configuration but report a value of 1.2 dBA for a single side piece of the same height and separation located on the source side of the barrier.

Morgan et al. [15] have investigated the performance of multi-edge barrier configurations alongside rail tracks by mathematical modelling and Hothersall et al. [16] have measured their performance using scale models. Although the results of these studies indicate that multi-edges can provide significant improvement, the source location, being very close to the barrier, with the resulting significant effect of inter reflections between source and barrier, and different noise spectra employed do not make these results relevant to the problem of highway noise.

Baulac et al. [5] have applied a multi criteria optimisation method to the design of multi-edge noise barriers. However, they restricted their investigation to two side pieces of height 1 m symmetrically located either side of the barrier. They examined the effect of varying the distance of the side pieces from the barrier and the properties of absorbent material (specified by flow resistivity and thickness) applied to the side pieces. They also examined the effect of inclining the side pieces. For vertical side pieces they achieved relative insertion losses of 4.5 dBA with absorptive side pieces located at an optimum distance of 0.9 m from the main barrier wall for a source to barrier distance of 8 m and receiver distance of 32 m.

Although the work of Baulac et al. gives a good indication of the maximum potential of this configuration it does not provide any information regarding how sensitive the performance of this device is to variations in edge length, which was maintained at 1 m, gap width and the relative locations of source, barrier and receiver. In this context, it should be noted that the optimum gap width was determined when constraining the gap width between 0.2 and 3.0 m. From a practical point of view, configurations with smaller edge lengths and narrower gaps will be cheaper to manufacture and present fewer structural problems when mounted on a barrier. Thus, if the performance is not very sensitive to variations in these parameters the highway engineer may well consider that a slight reduction in acoustical performance might be acceptable in the light of the other advantages.

Whilst the work described above suggests that additional edges applied to a barrier can be effective, there is no agreement amongst