Development and evaluation of roadside barriers to attenuate road traffic noise

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ABSTRACT

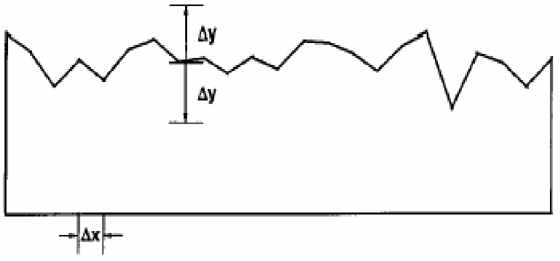
As part of a continuing program of investigations into roadside traffic noise barrier optimisation, the NSW Roads and Traffic Authority (RTA) funded a research and development study to develop and evaluate several full size prototype barrier designs. Of particular interest to this study was a design known as a Random Edge Profile Barrier since there was a body of published evidence which indicated that a barrier of this type can cause a substantial degradation of the noise diffracted over the barrier edge. As a consequence, it has been suggested that such barriers are capable of providing improved traffic noise attenuation compared to conventional barriers. The present study involved an empirical evaluation of a prototype Random Edge Profile Barrier and the comparison of its performance with that of conventional barriers and also with that which is known as a T-Top barrier. In total four barriers types were constructed alongside a major rural freeway in NSW and were 80m long by either 2.4m or 3.0m high. A substantial body of empirical data were collected at various receiver locations in front of, behind and adjacent to each barrier. Analyses of these data showed that for the receiver locations investigated, the random edge barrier out-performed the conventional barrier of the same nominal height for most frequencies associated with broadband tyre/road noise. The T-Top barrier was found to perform the best for frequencies greater than 3.15 kHz whilst the conventional barrier offered the most practical solution for attenuation of low frequency noise.

INTRODUCTION

In reviewing recent developments in the design, construction and performance of roadside noise barriers, Samuels (1999) and Samuels and Ancich (2001) found that barriers with novel cappings appeared to be capable of providing considerable increases in attenuation, particularly in the higher acoustic frequency regions. The implications of these findings were twofold.

- Capped barriers of the same height as conventional barriers could potentially provide greater noise reductions than the conventional barriers.
- A specified noise reduction could potentially be provided by a capped barrier of lower height than a conventional barrier.

The potential benefits were considered sufficient enough to warrant further investigation and the NSW Roads and Traffic Authority (RTA) subsequently funded a research and development study to conduct insitu empirical testing of several full size prototype barrier designs.



Source: (Ho, Busch-Vishniac & Blackstock, 1997)
Figure 1. Representation of a Random Edge Barrier Top.

Of particular interest to this study was a design known as a Random Edge Profile (or Jagged Edge) Barrier such as that presented in Figure 1. The available evidence (Ho et al 1997) was that a barrier with such an edge irregularity can produce increased insertion loss because the jagged edge causes a reduction in coherence of the diffracted signal being transmitted to the shadow zone compared to a conventional straight edge barrier. Both Menounou and Busch-Vishniac (2000) and Menounou and Ho (2004) have reported enhanced performance for Random Edge Barriers at higher frequencies but reduced performance at lower frequencies. In particular Shao et al (2001) and Ho et al (1997) indicated the cross over point in performance occurs around 2000 – 5000 Hz. This suggested that whilst there would be some benefits to reducing broadband road traffic noise, the critical areas of maximum acoustic energy which lie below 2000 Hz would not experience any improvement. Moreover, in most cases there would be degradation in performance as compared to a conventional straight edge barrier in this frequency range. Studies such as those cited above also indicated that these type of jagged edge barriers tend to perform better when the noise source is closer to the barrier. However, as yet there has been no full scale testing of random edge profile barriers.

THE EMPIRICAL STUDY

The study set up

The objective of the empirical study reported in the present paper was to undertake a full scale experiment to determine the insertion loss of a random edge barrier and to compare these results with those of conventional straight edge barriers and with that of a barrier with a T-Top configuration. A conventional 2.4m high barrier was constructed at the study site and was subsequently fitted with a T-Top. The T-Top was later removed and the conventional barrier was then increased in height to 3.0m, from which the upper 0.6m was later replaced with a random edge top. Thus the performance of four barriers were investigated in the study.

The study site was located on a section of the Hume Highway in NSW between Marulan and Goulburn. The barriers were constructed of a 28 mm timber laminate developed by Boral

Pty Ltd exclusively for use as a noise barrier. This laminate was provided in sheets that were 2.4 x 1.2m and were fixed between galvanized H beams. The barriers are shown in Figure 2. The various extensions and tops were also constructed of the 28 mm laminate and any gaps were suitably filled to eliminate any leakage. As finally constructed, the barrier was 80m long with an average setback of 22.3m from the south bound carriageway of the Hume Highway

2.4m T-Top Barrier

2.4m Conventional Barrier

3.0m Random Edge Barrier

Figure 2. Photographs of Barriers

Data collection and analysis

Four precision (Type 1) microphones were set up at various locations in front of, behind and away from each barrier configuration. Designated A, B, C and D, these microphones captured traffic noise data simultaneously at various combinations of the Measurement Points (MP's) shown in Figure 3 and listed in Table I. Extensive sets of data were collected for each barrier configuration. A 01dB Metravib Harmonie four channel analyser capable of collecting data from four microphones simultaneously at a sampling rate of 51.2 kHz was used to collect and analyse the road traffic noise data. Synchronised video footage of the roadway was also collected to allow identification and characterisation where necessary of the traffic noise sources such as those from individual vehicles or platoons. The analyses involved determining noise indices such as the L_{eq} and producing various frequency spectra of the traffic noise signals.

Figure 3. Plan sketch of the 8 Measurement Points adopted for each barrier configuration.

Table I. Measurement Points

Position	Measurement Point	In front or behind barrier	Location of measurement point relative to base of barrier	
			Height (m)	Distance from barrier (m)
At the barrier Microphones A,B & C	1	Front	1.2	2.4
	2	Behind	1.2	2.4
	3	Behind	1.2	4.8
	4	Behind	1.8	2.4
	5	Behind	1.8	4.8
Away from the barrier Microphone D	6	----	1.2	2.4
	7	----	1.2	2.4
	8	----	1.2	4.8

A summary of the key results: Noise levels

As indicated above there was a substantial set of data collected during the course of the investigation and subsequently a vast range of results ensued. Only the key results are summarised in the present paper. Firstly, the measured traffic noise L_{eq} levels at the five Measurement Points, averaged over four replicate samples at each Measurement Point, are set out in Table II. A carefully configured experimental design involving sequential, simultaneous monitoring at various combinations of four Measurement Points ensured that the data of Table II could all validly be compared against one another (Parnell 2005). Importantly, this experimental design also ensured that the data in Table II were, in effect, independent of the influences of factors such as fluctuations in the traffic volume, composition and speed during the measurements.

Table II. Measured traffic noise levels at the 5 Measurement Points at the barriers

Barrier Type	Averaged L_{eq} Traffic Noise Level (dB(A))				
	MP1	MP2	MP3	MP4	MP5
Conventional 2.4m	75.4	63.1	63.1	64.1	64.5
Conventional 3.0m	75.9	60.9	61.5	61.8	62.9
T - Top	76.3	62.1	62.6	64.3	65.7
Random Edge	75.6	60.9	60.4	62.1	61.1

From there, the barrier attenuations were determined from the Table II data. However prior to doing this, due allowance had to be made for the distance attenuation of the traffic noise propagating from the road to the Measurement Points. Parnell (2005) describes this process which involved analyses of the data collected at Measurement Points 6 to 8 which were away from the barriers (refer to Figure 3 and Table I). The following factors were thus obtained as being representative of distance attenuation between Measurement Points 1 to 5.

- 0.9 dBA was taken as the normal attenuation between MP 1 and MP 2/4
- 1.3 dBA was taken as the normal attenuation between MP 1 and MP 3/5

Barrier attenuations were calculated for each pair of replicate measurements allowing for the above distance attenuation. The ensuing barrier attenuations appear in Table III.

Table III. Average measured barrier attenuations.

Barrier Type	Averaged attenuation between MP 1 and MPs 2 to 5 in terms of L_{eq} (dB(A))			
	MP 2	MP 3	MP 4	MP 5
Conventional 2.4m	11.2	10.8	10.6	9.8
Conventional 3.0m	14.1	13.1	13.0	11.6
T - Top	12.9	11.9	11.4	9.6
Random Edge	13.8	13.9	12.6	13.1

It is apparent in Table III that the Conventional and T–Top Barriers were found to perform better at MP 2 (setback 2.4m, height 1.2m) than at MP 3 (setback 4.8m, height 1.2m) with decreases in attenuation for these barrier types ranging from 0.4 to 1.0 dB(A). However there was a corresponding increase for the Random Edge Barrier of 0.1 dB(A) which indicated that other processes were occurring for this barrier type. Increasing exposure to the traffic noise source from MP 3 to MP 5 resulted in decreases in attenuation for all barriers ranging from 0.8 to 2.5 dB(A), with the Random Edge Barrier again experiencing the lowest reduction. Increasing the height only from MP 2 to MP 4 (setback 2.4m, height 1.8m) resulted in decreases in attenuation ranging from 0.6 to 1.5 dB(A). This was also consistent with the expectation that there would be reduced shielding afforded by MP 4. Furthermore, increasing the setback of the elevated receivers from MP 4 to MP 5 (setback 4.8m, height 1.8m) resulted in the Conventional and the T-Top Barrier experiencing a reduction in attenuation of between 1.2 and 2.2 dB(A), whilst the Random Edge Barriers resulted in an increase in attenuation of 0.5 dB(A).

Returning to Table III it is clear that for all barriers there were reductions in attenuation from the most shielded receivers (MP 2 and 3) at 1.2m in height and those same positions when raised to 1.8m (MP 4 & 5). It is also apparent that the performance of the 2.4m T-Top barrier was approximately equal to, or better than the 2.4m Conventional Barrier. However this improvement seemed to apply only to the most shielded positions, with a negligible difference being observed between the two barriers at the most exposed location (MP 5).

The Random Edge Barrier with a nominal height of 3.0m was found to approximate the performance of a 3.0m Conventional Barrier at microphone locations (MP 2 & 4) close to the barrier. This barrier was however found to afford superior attenuation at greater setbacks (MP 4 & 5) than the 3.0m Conventional Barrier. It is interesting to note that there was a progressive improvement by the Random Edge Barrier relative to other barriers in the less shielded positions within the shadow zone.

A summary of the key outcomes across the frequency spectra

Typical outcomes of the study across the frequency spectra have been reproduced in Figure 4 which shows one set of attenuations for each of the four barriers (again having allowed for distance attenuation as before) in one third octave bands. Before interpreting what appears in Figure 4 it should be noted that road traffic noise is relatively broadband in nature and that the majority of acoustic energy, which is generated by tyre/road interaction, lies in the 250 Hz to 4 KHz range and sometimes down to 50 Hz (Sandberg & Ejsmont 2002, Samuels, 1982). The Portland Cement Concrete pavement in place at the study site tended to exhibit more discrete frequencies than some other types of pavements such as Dense Graded Asphaltic Concrete, however it provided traffic noise levels with an excellent signal to noise ratio for the measurements of the study.

For the 2.4m Conventional Barrier there was less than 3 dB attenuation recorded below 63 Hz which was considered negligible compared to what occurred at the other frequencies. An attenuation of about 10 dB was observed around 160 Hz at all Measurement Points and this rose to a maximum value of close to 18 dB at around 6.7 kHz for MP 2. The 3.0m Conventional Barrier offered an additional 2 dB attenuation below 31.5 Hz compared to the 2.4m Conventional Barrier. However the 3.0m Barrier did not afford any real improvement over the 2.4m Barrier in the 31.5 – 160 Hz range where 10 dB attenuation was observed at around 160 Hz. In the critical 800Hz – 2.5 kHz range there was an approximate 3 dB improvement by the 3.0m Barrier, however there was a corresponding drop for the higher frequencies above 3.15 kHz.

The T-Top barrier did not result in any improvements over the 2.4m Conventional Barrier below 125 Hz, however there was an approximate increase of 1 dB between 1.6 – 2.5 kHz, increasing to between 2 and 3 dB for frequencies greater than 2.5 kHz. The T-Top Barrier generally outperformed both of the Conventional Barriers between 250 – 500 Hz which are recognised as being important frequencies for road traffic noise (Campbell & Isles, 2001). However it was at frequencies greater than 3.15 kHz that the T-Top barrier out-performed the other barrier designs by the greatest margin.

While the Random Edge Barrier did not exhibit any improvement in attenuation over the 2.4m Conventional Barrier below 160 Hz, there was an increase between 0 and 4 dB between 160 Hz and 1 kHz. Up to 5 dB additional attenuation was recorded between 1 kHz and 2.5 kHz with general decreases above 3.15 kHz. The Random Edge Barrier was found to out-perform the T-Top Barrier in the frequency range from 250 Hz to 2.5 kHz and the 3.0m Conventional Barrier from 250 – 630 Hz for MP 2.

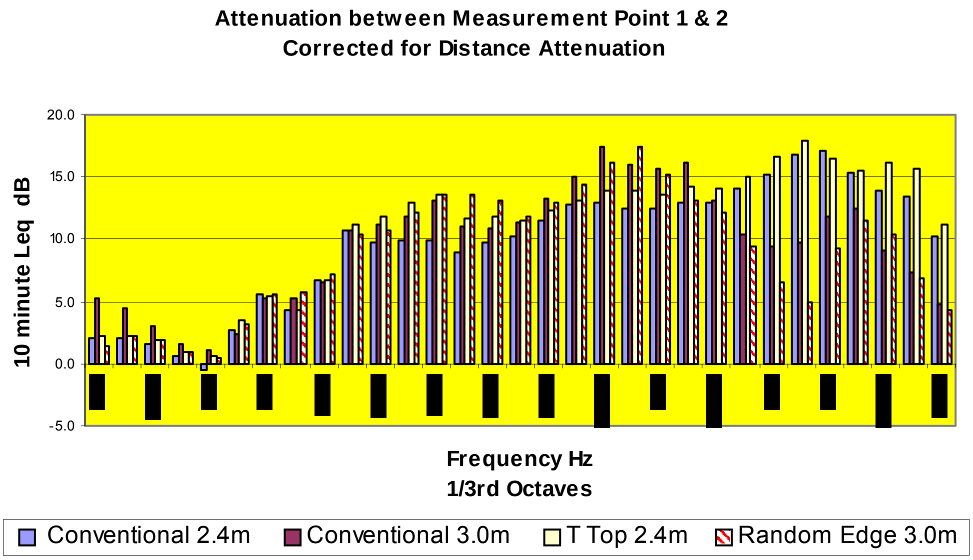


Figure 4. Attenuations determined in one third octave bands between Measurement Points 1 and 2 for each barrier.

At MP 3 the Random Edge Barrier outperformed the other barrier designs between 250 – 3.15 kHz. More specifically the Random Edge Barrier provided improved attenuation compared to the 3.0m Conventional Barrier for all frequencies of interest above 250 Hz and compared to the the T-Top between 250 – 3.15 kHz.Figure 5 shows the barrier insertion loss that was observed at MP 3 which is typical of the insertion losses determined at the other Measurement Points. Here it is apparent that in the critical frequency range between 250 Hz and 4 kHz the Random Edge Barrier out-performed all the other barrier types at almost all frequencies. These results, along with those from the various other Measurement Points, appear to be consistent with theoretical evidence that the random edge disrupts the coherence of the acoustic waves as they are diffracted by the barrier edge. This conclusion was also supported by the observations that the greatest differential improvement in insertion loss occurred at those locations close to the shadow/bright zone interfaces (MP 3 and 5).

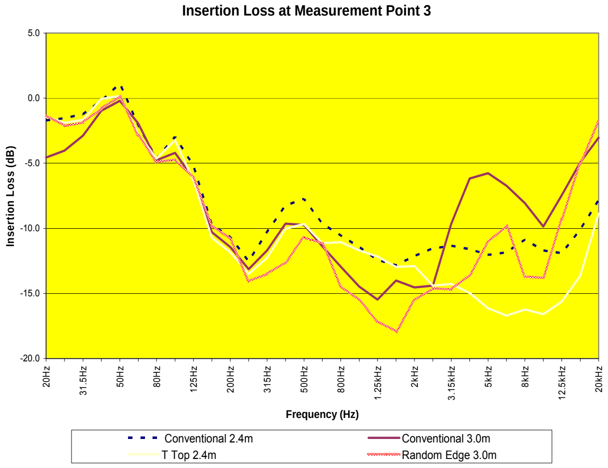


Figure 5. Insertion Loss at Measurement Point 3 for all four barriers.

CONCLUSIONS

Overall, the following conclusions ensued from the study reported in the present paper.

- The overall acoustical performances of the conventional noise barriers used in this study, which was limited to receivers being no further than 4.8m behind the barriers, were improved by introducing the novel barrier cappings, particularly at high frequencies.
- The Random Edge Barrier was found to out-perform the other noise barriers tested in this study over the frequencies that generally make up broadband road traffic noise. At the higher frequencies, particularly over 3.15 kHz, the T-Top Barrier performed best. For the lower frequencies below around 50 Hz, the 3.0m Conventional Barrier was found to afford superior attenuation. Low frequency noise can be generated by heavy vehicle engine compression brakes, therefore there may be no real advantage in utilising novel barrier tops in an attempt to address this particular issue.
- Earlier investigations reported in the literature had suggested that the crossover point for performance improvement between conventional barriers and random edge barriers typically occurred somewhere between 2 kHz and 5kHz. The conclusion of the present study is, however, that this crossover point is closer to 250 Hz for the barriers investigated. The implication of this finding is that Random Edge Barriers of the type studied may provide significant improvements in attenuating road traffic noise within the critical frequency bands of maximum acoustic energy.

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