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The use of in-situ test method EN 1793-6 for measuring the airborne sound insulation of noise barriers

By J Bull, G Watts and J Pearse

ABSTRACT

The in situ measurement of the airborne sound insulation, as outlined in EN 1793-6:2012, is becoming a common means of quantifying the performance of road traffic noise reducing devices. Newly installed products can be tested to reveal any construction defects and periodic testing can help to identify long term weaknesses in a design. The method permits measurements to be conducted in the presence of background noise from traffic, through the use of impulse response measurement techniques, and is sensitive to sound leakage. Factors influencing the measured airborne sound insulation are discussed, with reference to measurements conducted on a range of traffic noise barriers located around Auckland, New Zealand. These include the influence of sound leakage in the form of hidden defects and visible air gaps, signal-to-noise ratio, and noise barrier height. The measurement results are found to be influenced by the presence of hidden defects and small air gaps, with larger air gaps making the choice of measurement position critical. A signal-to-noise ratio calculation method is proposed, and is used to show how the calculated airborne sound insulation varies with signal-to-noise ratio. It is shown that the measurement results are influenced by barrier height, through the need for reduced length Adrienne temporal windows to remove the diffraction components, prohibiting the direct comparison of results from noise barriers with differing heights. (220 words)

Keywords: Noise barrier; Airborne sound insulation; EN 1793-6

1. INTRODUCTION

Measurement of the airborne sound insulation of noise reducing devices has been a subject of research in Europe over the past two decades, initially being investigated by European Commission funded projects “Adrienne” between 1995 and 1997 and more recently by “QUIESST” (2009-2012)[1]. The research focused on designing a method for measuring the sound absorption and airborne sound insulation of noise reducing devices. Verification of the measurement method has been conducted [2,3] and a test standard initially released by the European Committee for Standardization (CEN) as CEN/TS 1793-5:2003 [4]. This standard was concerned with measuring both the sound reflection and airborne sound insulation; the measurement of the airborne sound insulation was later released individually as EN 1793-6:2012 and adopted by British Standards Institution [5]. As part of this work it was necessary to consider the repeatability and reproducibility in order to assess the uncertainty of the method [6]

The measurement technique (EN 1793-6) has benefits over traditional laboratory measurements in terms of its ability to assess the performance of a noise reducing device in situ, where installed products may exhibit a drop in acoustic performance over time [7]. Changes in the acoustic performance of a noise barrier over time can be assessed through periodic airborne sound insulation measurements, and concerns of the public over degradation can be quantified and compared to historical data prior to undertaking any remedial work. Measurements can be conducted in the presence of background noise due to the use of impulse response measurement techniques using deterministic excitation signals. It should noted that these test signals can include MLS (Maximum Length Sequence) and ESS (Exponential Sine Sweep), which may give slightly different results in critical conditions [8]. For this study the MLS test signal has been employed.
For comparing products, the concept of a single number rating was introduced. This weights the individual airborne sound insulation indices at different third-octave band frequencies with a standard traffic noise spectrum defined in EN 1793-3 [9].

Large scale testing programs have been conducted using CEN/TS 1793-5:2003, with the in situ results correlating well with laboratory measurements made using EN 1793-2:1997 [2,3,11].

Sound leakage will appear to degrade the performance of a noise reducing device when measurements are performed near air gaps, with the distance between the microphone and air gap having a significant effect on the apparent performance [11]. In fact, boundary element models (BEM) have shown that sound leakage is likely to have a detrimental effect on the overall performance within 80 metres of the barrier [12].

2. SIGNAL-TO-NOISE RATIO

The calculation of the signal-to-noise ratios of a measured impulse response is necessary to ensure that the measurements are not affected by background noise; EN 1793-6:2012 calls for an effective signal-to-noise ratio of at least 10 dB. A calculation method has been proposed [13] that makes use of two segments of the measured impulse responses, one representing the “signal” and the other representing the “noise” (Figure 1). The “noise” segment is taken from the part of the impulse response immediately preceding the arrival of the directly transmitted sound, hence limiting the segment length to 3.5 milliseconds and giving the calculation a low frequency limit of 400 Hz.

Due to the effect of time aliasing, the initial part of the impulse response that precedes the arrival of the transmitted sound is governed by the tail of the impulse response [14]. Note that this effect is not apparent when using an ESS signal [8]. Therefore, the “noise” segment used for signal-to-noise ratio calculations in this work is based on a segment of the impulse response tail (Figure 2). The same Adrienne temporal window used to remove the diffraction components may then be used to generate the “signal” and “noise” segments, thereby giving the same low frequency limit as the airborne sound insulation calculations.

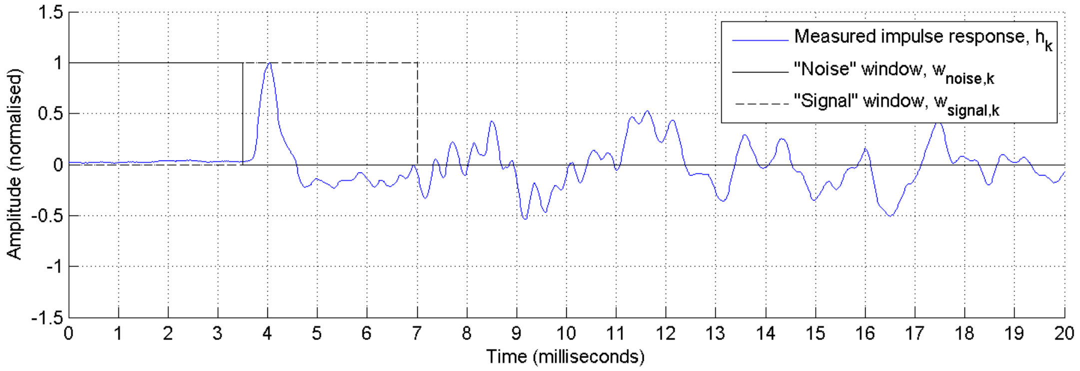

Figure 1: *Signal-to-noise ratio calculation method defined in [11], valid above 400 Hz*

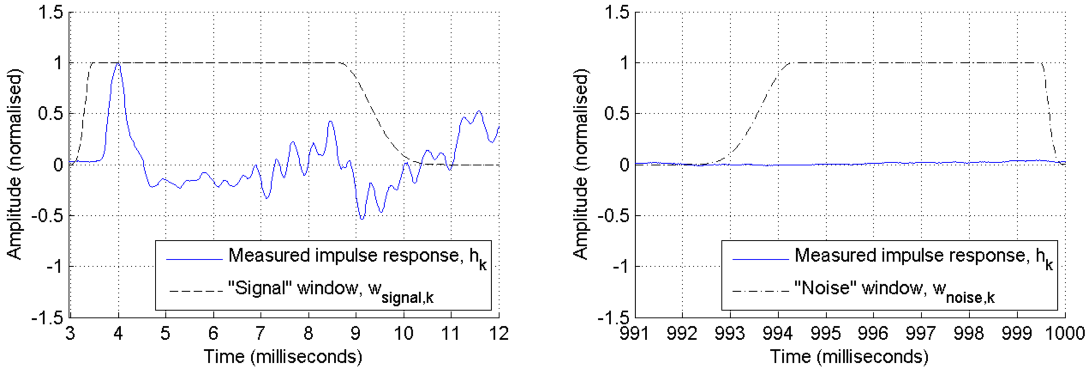

Figure 2: *Modified signal-to-noise ratio calculation method for a 1 s long impulse response, valid over the full measurement frequency range of a particular measurement*

The signal-to-noise ratio is calculated in each one-third octave band, in the valid measurement frequency range, using Equation 1.

$$\mathrm{SNR}_{SI,k,j} = 10\log_{10}\left\{\frac{\int\limits_{\Delta f_j} \left|F[h_k(t)w_{signal,k}(t)]\right|^2 \,\mathrm{d}f}{\int\limits_{\Delta f_j} \left|F[h_k(t)w_{noise,k}(t)]\right|^2 \,\mathrm{d}f}\right\} \qquad (1)$$

Here $h_k(t)$ is the measured impulse response at the k th microphone position, $w_{\mathrm{signal},k}(t)$ is the Adrienne temporal window for the “signal” evaluation of the impulse response (identical to that used during airborne sound insulation calculations), $w_{\text{noise},k}(t)$ is the Adrienne temporal window for the “noise” evaluation of the impulse response (placed at the end of the measured impulse response), j is the index of the one-third octave bands in the valid measurement frequency range, F is the symbol of the Fourier transform, and Δf_j is the width of the j th one-third octave band.

3. SOUND LEAKAGE

The influence of sound leakage on the measured airborne sound insulation depends on the size, number and location of the defects involved. Two types of sound leakage were identified from the Auckland noise barrier testing work: that due to small defects, and that due to larger air gaps.

Small defects result in a reduced sound insulation index at the high frequencies. This is typical of element-post joints with inadequate sealing resulting in differences between the airborne sound insulation of the elements and posts. Measurements on the engineered timber noise barrier are shown in Figure 3. Measurement positions 1 and 3 are of barrier elements. Measurement position 2 is of a barrier post. A notable drop in performance above 2000 Hz can be seen.

Airborne sound insulation measurement results from a slatted timber noise barrier are shown in Figure 4. This barrier had an even distribution of small air gaps along its length, and shows poor performance at high frequencies, similar to the engineered timber noise barrier. In this case the performance was compromised at frequencies above 1250 Hz.

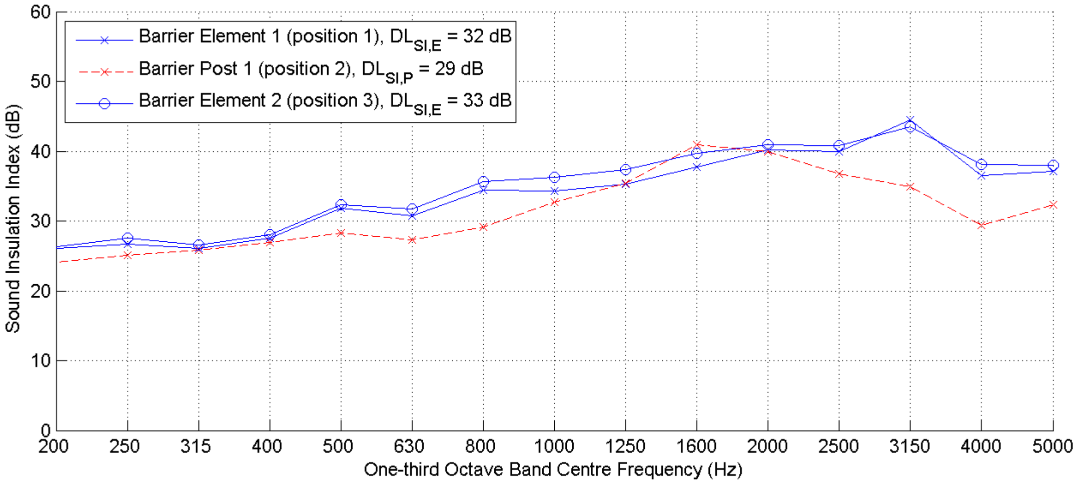

Figure 3: *Sound insulation index and single number ratings for the engineered timber noise barrier*

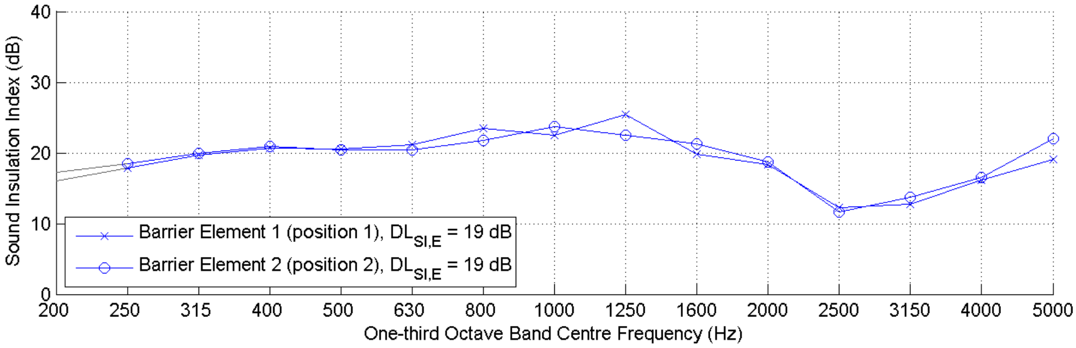

Figure 4: *Sound insulation index and single number ratings for the timber noise barrier. Values below the low frequency limit of the measurements are not shown*

When larger air gaps are present in a barrier, the measured airborne sound insulation can depend heavily on the position of the microphones relative to the air gaps. This effect has been demonstrated by previous modelling work and measurements, which show that the distance between an air gap and receiver can significantly affect the results [11,12].

Figure 5 includes two measurements on the same element at two different heights. The barrier involved consisted of a 3.2 metres high acrylic noise barrier mounted on top of a 1.2 m high concrete safety barrier. A 3mm wide gap was present between the safety barrier and noise barrier components.

Measurement position 1 was at a height of 2.5 m above the ground (1.3 m above the safety barrier), while measurement position 2 was at a height of 2 m above the ground (0.8 metres above the crash barrier). This meant that the microphones were located nearer to the air gap during measurements at position 2. The measured airborne sound insulation is lower for measurement position 2, indicating that more sound energy is reaching the microphones. The single number rating ($DL_{SI,E}$) drops by 2 dB at the lower height measurement position.

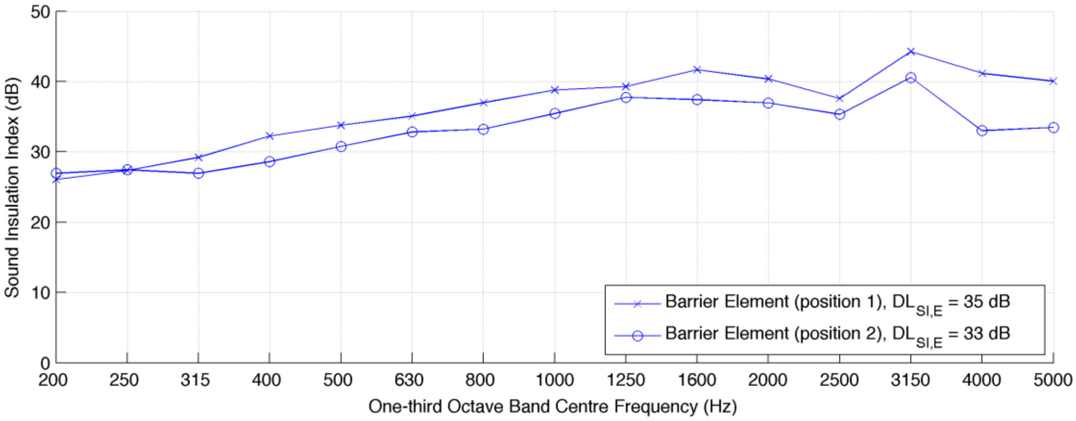

Figure 5: *Sound insulation index and single number ratings for the acrylic noise barrier*

4. BARRIER HEIGHT

The measured airborne sound insulation is affected by the height of the noise reducing device. Sample noise barriers constructed specifically for testing to EN 1793-6:2012 are required to have a height of 4 m; however, in situ measurements on existing noise barriers with heights other than 4 m may also be conducted. For noise barriers with heights of less than 4 m the shorter arrival time of the diffracted sound wave requires the use of a reduced length Adrienne temporal window, resulting in a reduced measurement frequency range due to insufficient detail at the low frequencies.

The frequency dependent sound insulation index changes with Adrienne temporal window length. This is a consequence of truncating the component of the impulse response due to the transmitted sound wave, and the effective reduction of the sample test area resulting in the inclusion of fewer leakage components, where present. Figure 6 shows the barrier and free-field impulse responses for a 4.2 m high noise barrier; the signal energy excluded when using a shortened Adrienne temporal window can be seen. The result is an increase in the measured sound insulation index of the noise reducing device (Figure 7).

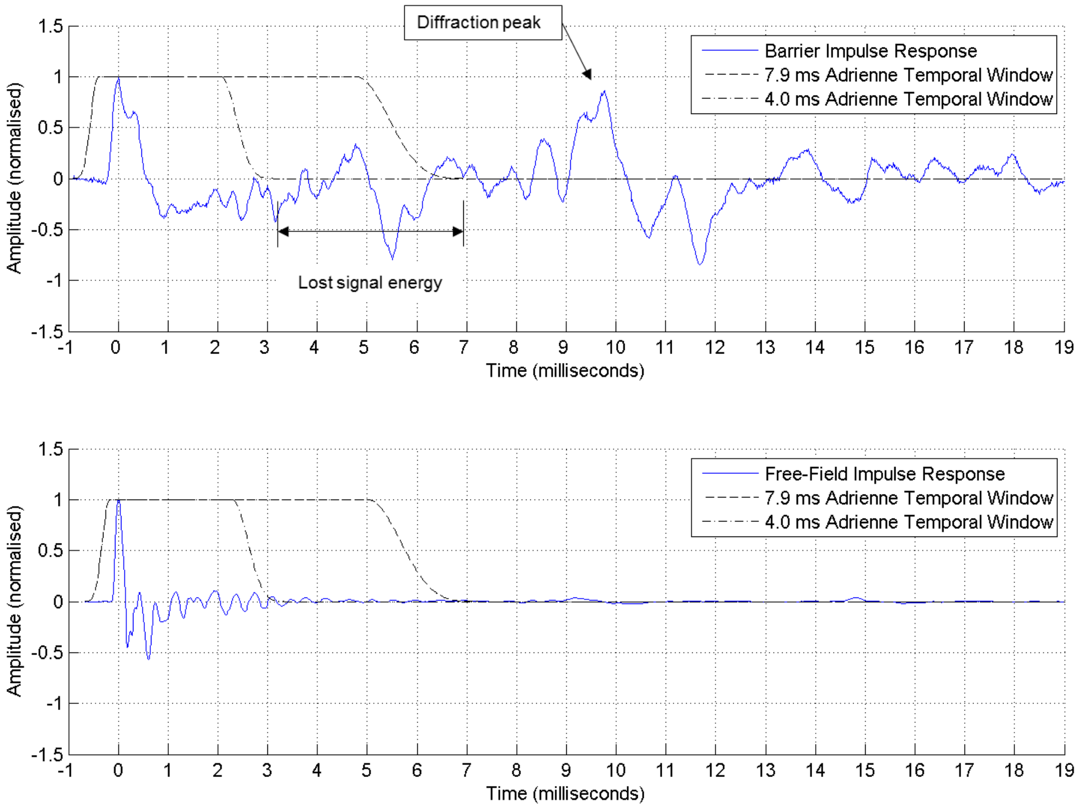

Figure 6: *Barrier and free-field impulse responses with two different length Adrienne temporal windows; the signal energy excluded when using a shortened window can be seen*

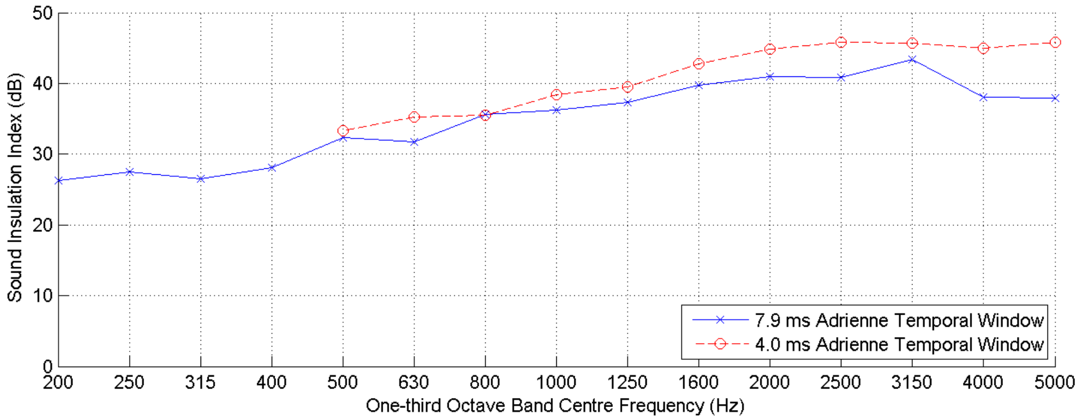

Figure 7: *Sound insulation index for a 4.2 m high noise barrier calculated using two different length Adrienne temporal windows; values below the low frequency limit are not shown*

The single number rating of airborne sound insulation is calculated over the valid measurement frequency range. The effect of the modified frequency range on the single number rating is investigated by keeping the Adrienne temporal window length constant (7.9 ms) but increasing the low frequency limit. The result is an increase in the calculated single number rating (Table 1).

These two phenomenon make it necessary to consider barrier height when comparing airborne sound insulation measurements, with direct comparisons requiring a common length Adrienne temporal window to be used. This is important in the context of New Zealand road traffic noise barriers where many of the currently installed noise barriers are shorter than 4 m.

Table 1: *Single number ratings of airborne sound insulation for a 4.2 m high noise barrier, showing the variation due to different measurement frequency ranges*

Low Frequency Limit	***Single Number Rating of Airborne Sound Insulation***
200 Hz	33 dB
315 Hz	35 dB
500 Hz	37 dB

5. CONCLUSIONS

Measurements performed on noise barriers in Auckland were used to investigate the effects of signal-to-noise ratio, sound leakage and barrier height on the measured airborne sound insulation.

A new method for determining the signal-to-noise ratio was proposed, allowing calculation of the signal-to-noise ratios in each valid one-third octave frequency band.

Sound leakage due to small defects decreases the sound insulation index at the high frequencies. The engineered timber noise barrier exhibited this behaviour in the region of an element-post joint, indicating a poor seal. While the slatted timber noise barrier showed poor performance above 1250 Hz at two measurement positions. This was attributed to the even distribution of small air gaps along its length. Larger air gaps tended to cause a decrease in the sound insulation index across the entire measurement frequency range, and depended on the distance between the microphones and air gap.

Many noise barriers located around New Zealand have heights of less than 4 m, requiring a reduced length Adrienne temporal window to remove the diffracted sound wave. This causes a truncation of the component of the impulse response due to the transmitted sound wave, as well as a reduction in the sample test area resulting in the inclusion of fewer leakage components. Both of these factors tend to increase the sound insulation index of shorter noise barriers. The single number rating is calculated over the valid measurement frequency range, and this causes a further increase in the calculated airborne sound insulation. Consideration of the low frequency limit needs to be made when comparing the airborne sound insulation of noise barriers with differing heights.

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