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THE INFLUENCE OF TOP FINISHING OF THE NOISE BARRIER ON ITS ACOUSTIC PERFORMANCE – FIELD EXAMINATION

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Abstract

Field measurements were made in order to examine the acoustic performance of a noise barrier built along a railway track depending on its top finishing. Three cases were considered: a reference barrier made of wood-cement panels, the same barrier topped with a highly absorptive flat panel, and the same barrier topped with a highly absorptive T-top section. The measurements were made at four distances from the barrier at the protected side, and at three different heights, giving a total of twelve receiver points. A reference measurement was made on the source side of the barrier as well. Instead of a train, a loudspeaker reproducing pink noise was used as the sound source. The attenuation between the reference microphone and each receiver point was calculated. The reference spectrum of railway noise was then used to simulate its foreseen spectrum at each receiver point. The final results were expressed as the overall A-weighted noise level the reference railway noise spectrum would have at each receiver point, and the improvement of acoustic performance of the barrier was assessed. The improvement is evident with both flat- and T-top in comparison with no top due to added height. The T-top finishing gives additional improvement over the flat finishing. The effect is more pronounced at lower heights and shorter distance between a receiver point and the barrier. Based on the measured values, the equivalent additional height of a flat barrier was calculated that would yield the same improvement as the added T-top section.

Keywords: railway noise, noise barrier performance, top finishing.

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1 Introduction

The basic shape and construction of a noise barrier is a flat, vertical wall made of acoustically hard material with ideally infinite acoustic impedance. Such a barrier can be easily described in mathematical terms and an analytic solution that describes the performance of the barrier can be found. However, such a barrier, although easy to construct and describe, is hardly the best possible solution for every situation that occurs in practice.

Therefore, many different techniques have been investigated [1] to improve noise barrier performance and their ability to shield the protected zone on the receiving side of the barrier from excess noise levels produced by sources on the source side. A few examples include tilting the barrier to stand at an angle away from perfectly perpendicular to the ground, laying absorptive materials to portions of the barrier on the source side, changing the shape of the barrier from flat to cantilevered or galleried ones,

or, recently, to optimize the cross-section of a barrier using genetic algorithms [2]. A group of techniques deals with the diffraction on the top of the barrier as the principal source of noise for the protected zone, and proposes adding a diffusive element to the top of the barrier as a mean of reducing that diffraction component. Hothersall et al. [3,4,5] investigated the behaviour of barriers with spherical, Y- and T-shaped top finishing compared to plain flat barrier, as well as Ishizuka and Fujiwara [6], who also did major work in investigating the performance of barriers with diffusers added to the top.
To experimentally show the benefits of attending to the problem of diffraction at the top of the barrier and to confirm the findings of earlier research, field measurements were made on a real true-scale barrier placed along a railway track. The methodology and the results of these measurements are presented below.

2 Measurement setup and data analysis

The task described in the paper consists of field measurements on a noise barrier intended for reducing railway noise. Consequently, the barrier on the test site was placed right beside the railway track, as close to the rails as possible, without compromising the safety. The idea behind these measurements was to examine the ability of these noise barriers to reduce the noise level depending on the shape of the top finishing element of the barrier, and on the total height of the barrier.
The barrier itself had the length of 256 m, and as such was long enough to prevent the diffraction from the ends of the barrier to become significant. The measurements were made for three different configurations of the noise barrier. The first, basic configuration involves the noise barrier made of wood cement panels with a height of 2.14 m above the rails. In the second configuration a flat absorptive element with a height of 0.5 m is added onto the basic barrier as the top finishing, thus increasing the total height of the barrier to 2.64 m. In the third configuration the flat absorptive element is replaced with a T-shaped highly absorptive element of the same height, which leaves the total height of the barrier at 2.64 m. The configurations are sketched in Figure 1 and shown in the photos in Figure 2.
Due to complexity, time and great effort required to change the configuration of the barrier, the measurements were made on two different days with a time gap of 12 days. The time gap was made as short as possible to avoid the influence of seasonal changes of meteorological conditions on the results. Care was taken to monitor the weather forecast and to choose the second measurement day in such a manner that the meteorological conditions on two measurement days would be as similar as possible. The planned and later realized dynamics of the measurements enabled the same measurement stages to be executed at the same time of the day, thus helping avoid the influence of short-term changes of meteorological conditions during the day on the results.
Due to safety reasons, the railway track was closed during the measurements. Therefore, a real noise source, i.e. the passing of a train, could not be used as the noise source required for the measurements. To accommodate for this and to achieve a better repeatability of the measurements, a pair of active PA speakers driven with pink noise were used as the noise source. The loudspeakers were put in the middle between the rails to ensure that the position of the pink noise source coincides with the position of the real source, i.e. the wheels rolling on the rails. The loudspeakers were tilted at an angle away from the ground, so that they could overshoot the barrier and provide enough sound pressure at the measurement points on the protected side. For the same reason, the reference overall sound pressure level measured at 1 m in front of the loudspeakers was set as high as possible, without triggering the protective circuits in the loudspeakers that change the spectrum of the emitted sound. To capture the reference signal on the source side of the barrier, a reference microphone was placed in front of the barrier on a predefined position. The overall sound pressure level in this position was measured to be

102 dBA. The sketch drawing of the measurement setup on the source side of the barrier is shown in Figure 3.

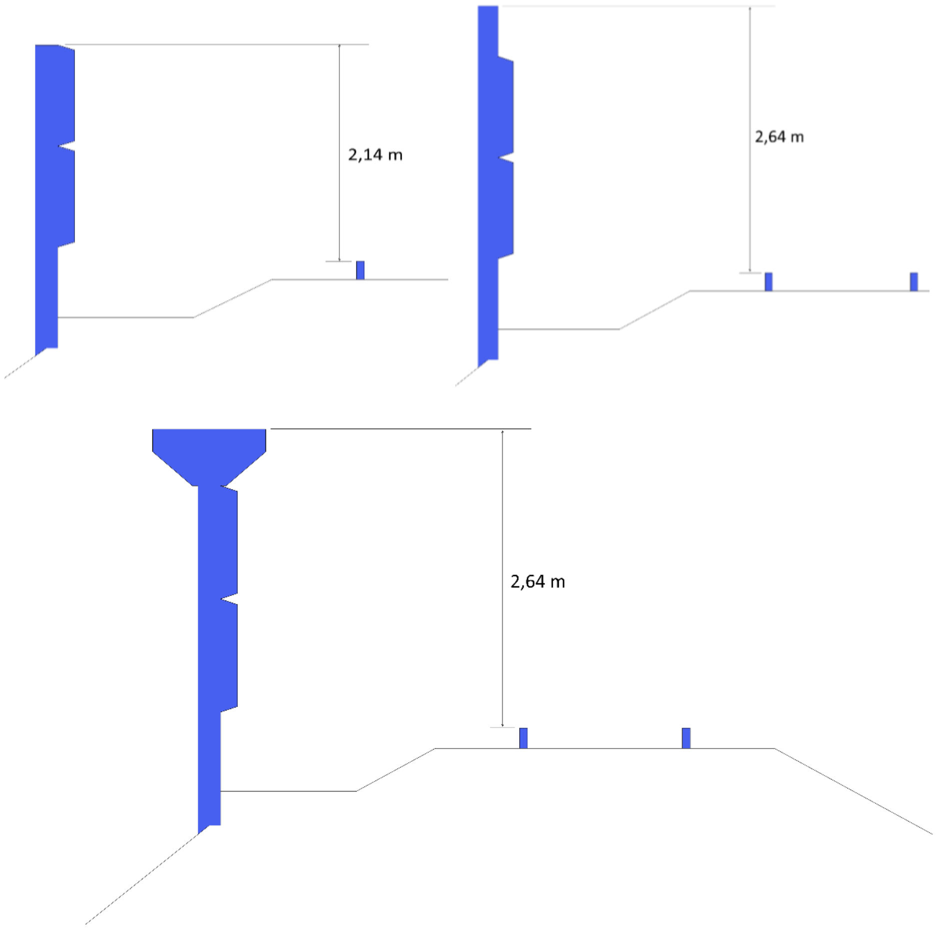

Figure 1 – The sketches of the investigated barrier configurations

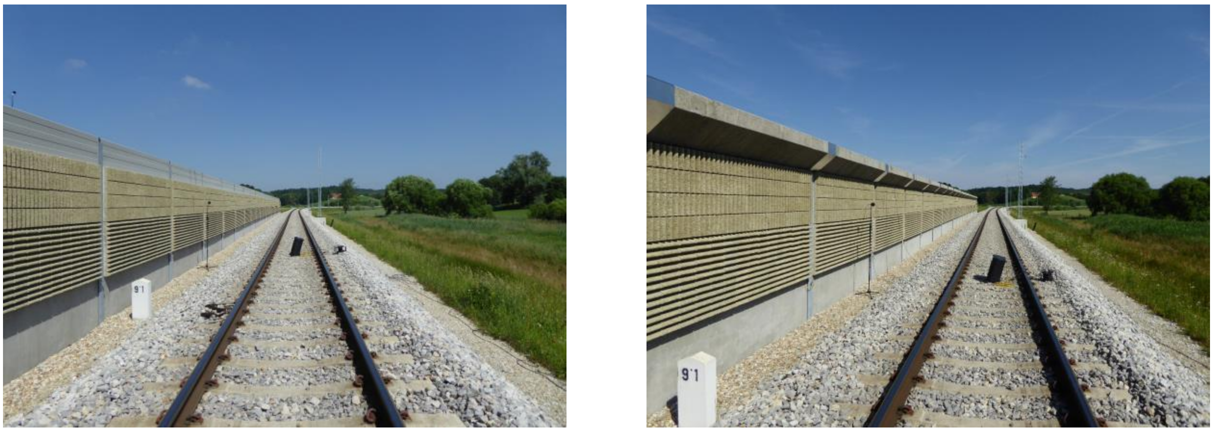

Figure 2 – The photos of the investigated barrier configurations – flat absorptive finishing and T-finishing

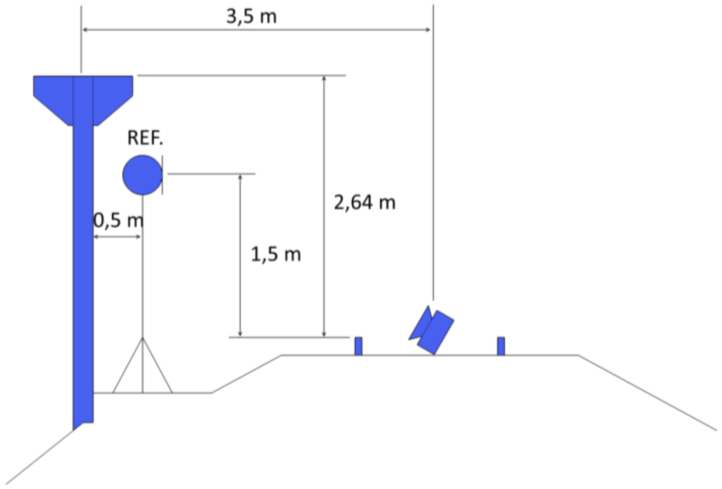

Figure 3 – Measurement setup at the source side of the barrier

Measurement positions behind the barrier, i.e. on the protected side of the barrier, were set at four distances, namely, 6, 12, 24 and 48 m from the barrier, and named accordingly as P6, P12, P24 and P48. The initially planned measurement distances of 25, 50 and 100 m from the barrier were eventually dismissed, as it would have been impossible to set up the measuring equipment on all of them due to the nearby houses.
At each measurement point, the measurements were performed at three different heights. The middle measurement height was the reference height H that corresponds to the height of the barrier with a top finishing element added onto it. The lower measurement height H-2.5 m roughly corresponds to the height of the rails, and the upper measurement height H+2.5 m was chosen to see how the sound propagates in the region above the barrier height.
To determine the noise reduction efficiency of three different configurations of the noise barrier, and, consequently, the differences between them, noise level was measured on the reference point at the reference side of the barrier, i.e. in front of it, and in several measurement points on the protected side of the barrier, i.e. behind it. To maintain measurement uncertainty at acceptable levels, class 1 microphones were used in all measurements. A total of four microphones was used, one of which was fixed in the reference position, while the remaining three were set on each of the four defined measurement positions at three defined heights. To maintain the required height difference between these microphones, all three of them were mounted on a microphone stand, which was then moved from one measurement point to the next for each measurement. Due to the lack of an adequate number of microphones, the measurements could have been made only sequentially, as described, i.e. at one measurement point at a time. For this reason, the absolute sound pressure level was checked before and after each measurement by recording the 1 kHz calibration tone at 94 dB. A sketch of the microphone setup and the positions of the measurement points on the protected side of the barrier is shown in Figures 4 and 5. The photo of the measurement microphones on the P6 measurement point is shown in Figure 6.

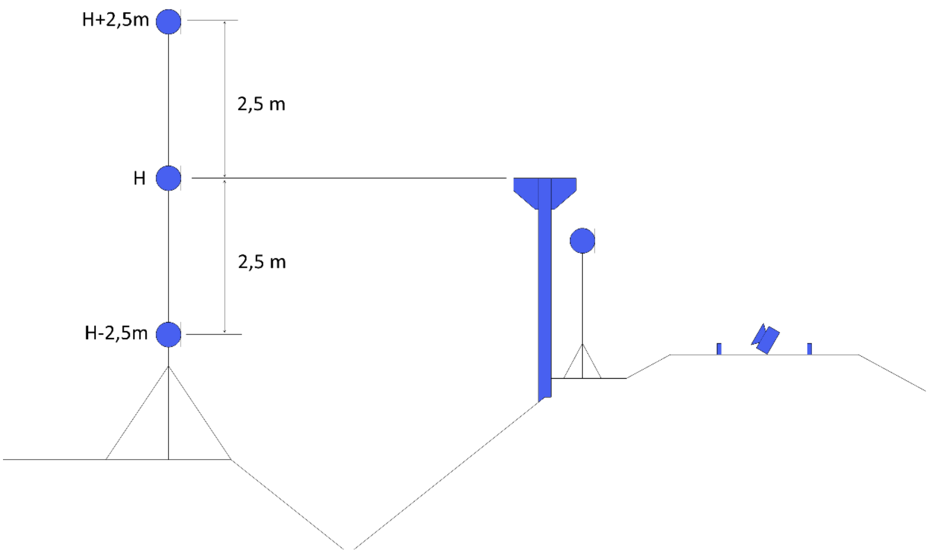

Figure 4 – Sketch of the measurement setup at the protected side of the barrier

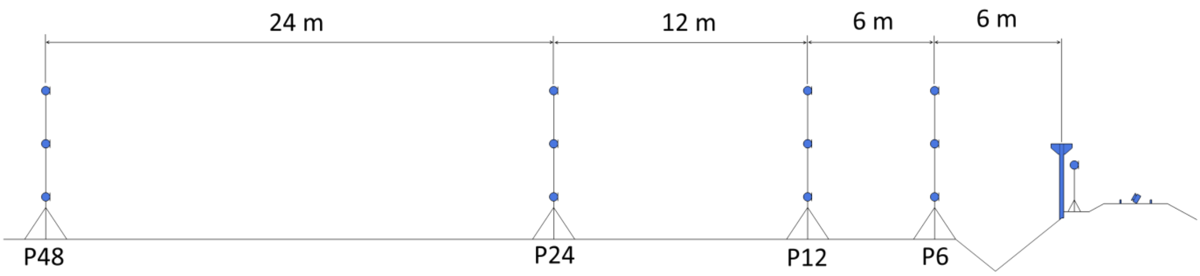

Figure 5 – Sketch of the positions of the measurement points on the protected side

Figure 6 – A photograph of the measurement point P6 on the protected side of the barrier

To obtain the required noise levels, steady pink noise was reproduced by the loudspeakers acting as the noise source. The signals received by the all the microphones were directly recorded as waveforms in a dedicated software. Representative excerpts with the length of 15 seconds were made from those recordings, taking into account that all these excerpts have to be cut out in the same time interval. The excerpts were analysed in MATLAB using the Psysound3 application. The correct sound pressure levels were obtained by taking into account the 1 kHz calibration signal which was recorded as well. All excerpts were analysed spectrally with the usual 1/3-octave resolution.
Excerpts of background noise present in the environment were recorded as well, in order to determine its influence on the measurements.
The overall A-weighted levels and the 1/3-octave band spectra had been obtained for the reference point, all measurement points and background noise data. After that, the noise spectra at all measurement points was corrected to take into account the influence of background noise. Apart from a few exceptions in individual 1/3-octave bands, the levels in 1/3-octave bands measured for the received noise signals were at least 10 dB higher than the corresponding levels of background noise, making the correction either small or negligible.
The noise reduction efficiency of the barrier, i.e. the frequency-dependant attenuation between the reference point on the source side and each of the measurement points on the protected side of the barrier, was calculated by subtracting the corrected noise spectra obtained in the corresponding measurement point from the noise spectra obtained in the reference point. This was done for all three investigated configurations and all measurement points.
The last step of the analysis was to calculate the noise spectra and the overall A-weighted noise levels in each of the measurement points taking into account the spectral characteristics of a real source, i.e. a passing train. To do this, the normalized railway noise spectrum, shown in Figure 5, given in [7] as A-weighted normalized 1/3 octave band levels in frequency bands between 100 Hz and 5 kHz (the overall A-weighted level is 0 dBA) was taken as the source spectrum. Knowing the attenuation between the reference point and the measurement points, the resulting noise spectra in the measurement points were easily found.

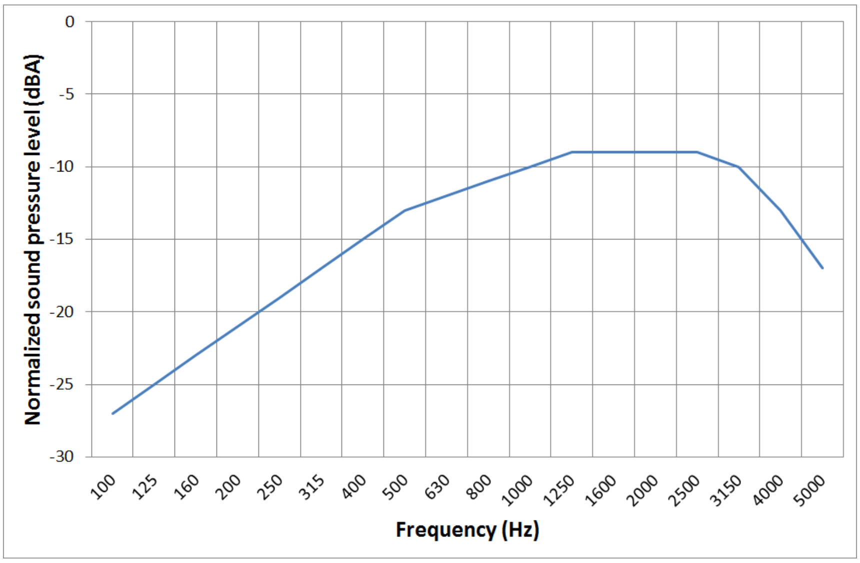

Figure 7 – Normalized railway noise spectrum [7]

3 Results

The values of noise attenuation are presented for all three configurations of the noise barrier at all four measurement points and for all three measurement heights. As the focus of the work was to examine the possible improvement a straight absorptive element and/or a T-shaped element would bring to the basic barrier configuration, the results are referenced to noise attenuation of the basic barrier. In other words, only the difference in attenuation between the basic barrier and the one topped with flat and T finishing is presented. The summarized results are presented in Table 1.

Table 1 – Summarized measurement results

<table>
<tr><th rowspan="2">Measurement point</th><th rowspan="2">Distance from the barrier (m)</th><th rowspan="2">Microphone height (m)</th><th colspan="2">Improvement in noise attenuation relative to the basic barrier (dB)</th><th rowspan="2">Improvement in noise attenuation with the T-top relative to the flat top (dB)</th><th rowspan="2">Additional barrier height that would give the same attenuation as the T element (m)</th></tr>
<tr><th>Flat</th><th>T</th></tr>
<tr><td rowspan="3">P6</td><td rowspan="3">6</td><td>H - 2,5</td><td>2,3</td><td>4,8</td><td>2,5</td><td>2,0</td></tr>
<tr><td>H + 0</td><td>2,3</td><td>3,6</td><td>1,3</td><td>0,3</td></tr>
<tr><td>H + 2,5</td><td>3,5</td><td>4,6</td><td>1,1</td><td>0,15</td></tr>
<tr><td rowspan="3">P12</td><td rowspan="3">12</td><td>H - 2,5</td><td>2,4</td><td>4,4</td><td>2,0</td><td>1,3</td></tr>
<tr><td>H + 0</td><td>1,0</td><td>1,7</td><td>0,7</td><td>0,2</td></tr>
<tr><td>H + 2,5</td><td>2,6</td><td>3,6</td><td>1,0</td><td>0,2</td></tr>
<tr><td rowspan="3">P24</td><td rowspan="3">24</td><td>H - 2,5</td><td>2,2</td><td>2,9</td><td>0,7</td><td>0,3</td></tr>
<tr><td>H + 0</td><td>0,9</td><td>2,3</td><td>1,4</td><td>0,5</td></tr>
<tr><td>H + 2,5</td><td>1,9</td><td>2,9</td><td>1,0</td><td>0,3</td></tr>
<tr><td rowspan="3">P48</td><td rowspan="3">48</td><td>H - 2,5</td><td>0,8</td><td>2,6</td><td>1,8</td><td>1,0</td></tr>
<tr><td>H + 0</td><td>1,4</td><td>1,7</td><td>0,3</td><td>0,15</td></tr>
<tr><td>H + 2,5</td><td>0,5</td><td>0,5</td><td>0,0</td><td>0,0</td></tr>
</table>

As expected, the addition of either the flat or the T finishing on top of the basic barrier results in improved performance of the barrier with respect to the basic configuration, greatly due to the 0.5 m increase in total height of the barrier. The results also show that the improvement is greater with the T top added to the barrier, as directly shown in the second rightmost column of Table 1, and is in the range of 0 to 2.5 dB, depending on the distance from the barrier and microphone height.
The data on improvement of barrier performance of a T-topped barrier relative to the flat-topped one served as the input to the calculation of the height of the flat barrier that would have the same attenuation as the T-topped one. This calculation gave the data on how much height can be saved by installing a T element on top of the barrier, as shown in the rightmost column of Table 1. The general conclusion is that the height reduction is considerable for positions close to the barrier and at the lowest height, which is directly related to the largest improvement in barrier performance at these positions.

4 Conclusions

The results of the field measurements conducted for three different configurations of a noise barrier show that the efficiency of the noise barrier, built to protect the environment from railway noise, increases when a finishing element is added to the top of the barrier. By doing so, the height of the barrier is increased, and with all other elements left unchanged, the barrier performance is improved. However, the characteristics of the added top finishing element also have an influence on barrier efficiency.

Specifically, adding a highly absorptive flat element with the height of 0.5 m on top of the basic configuration of the barrier (height 2.14 m, material: wood-cement panels on concrete) yields the increase of noise attenuation on all measurement points behind the barrier. The increase is in the range from 0.5 to 3.5 dB, depending on the distance from the barrier and relative height to the rails as the reference point. The best results were obtained close to the barrier and to the ground, as expected.

Replacing the highly absorptive flat finishing element with a highly absorptive T-shaped one of the same height yields an additional increase in barrier attenuation of 0 to 2.5 dB, again, depending on the distance from the barrier and the height. As before, the best results were obtained close to the barrier and near the ground.

The increased efficiency of the T-top finishing was analysed from the viewpoint of the possible height reduction of a flat barrier when equipped with such a T-top element. The results show that the height of an otherwise flat barrier can be reduced by up to 2 m, with the efficiency maintained, if the barrier is equipped with a T-top finishing, assuming the reference spectrum of railway noise given in [7]. Again, the projected height reduction depends on the location and height of the measurement point, being the largest for measurement points close to the barrier and to the ground.

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