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ASSESSMENT OF THE EFFICIENCY OF A WHISTOP DIFFRACTOR FOR ROAD TRAFFIC NOISE ABATEMENT

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ABSTRACT

The WHIStop is a lightweight aluminum diffractor designed to enhance the performance of existing noise barriers by deflecting sound upwards. Reportedly, the WHIStop achieves a 4–5 dB noise reduction, comparable to increasing the barrier height by 2 meters. To test and evaluate the efficacy of a WHIStop in Ireland, Transport Infrastructure Ireland (TII) recently commissioned a test installation along a motorway section in the west of Ireland. As part of this assessment noise measurements were conducted at two fixed locations under three conditions: i) baseline with no mitigation; ii) after the installation of a 3m high noise barrier; and iii) after adding the WHIStop diffractor. Initial results suggest the WHIStop has had a positive impact on noise levels immediately behind the barrier. To further assess the acoustic impact, an acoustic camera was deployed to further assess the impact of the WHIStop on site. Several characteristic changes were observed, including a change in acoustic roughness, while a spectrogram analysis revealed a shift in the perceived Doppler effect. These findings highlight the WHIStop's potential in altering and mitigating traffic noise effects for adjacent neighbourhoods.

Keywords: *diffractor, noise control, road traffic noise, abatement.*

1. INTRODUCTION

The WHIStop is a lightweight aluminium diffractor, that can be mounted onto any (existing) noise barrier to deflect sound upwards [1]. It is reported that the WHIStop can add a 4 to 5 dB noise reduction, comparable to raising the existing barrier 2 meters [1].

To assess the performance of the WHIStop diffractor, TII commissioned the installation of a test section along a motorway in the West of Ireland. Prior to the installation of the test section, noise measurements were conducted at two fixed locations in the vicinity of the barrier. Measurements were then repeated after the installation of the WHIStop. This paper presents the results of those measurements.

2. SITE MEASUREMENTS

The following conditions are considered:

a) Baseline Condition (No Noise Mitigation)
b) After Noise Barrier Installation (No WHIStop)
c) After WHIStop Installation (Noise Barrier & WHIStop).

2.1 Condition A - Baseline

A baseline measurement campaign was undertaken at the test, before the installation of a noise barrier (independent of the WHIStop). During this campaign no noise barrier was in place. Unattended noise monitors were installed at two locations representing the closest and farthest of a group of five properties west of the motorway. The unattended noise monitors were installed for a period of 14 days from the 4th of November 2021 to the 17th of November 2021. NSL1 is approximately 50m from the roadside edge, while NSL2 is approximately 150m from the roadside edge. It should also be noted that the road extends to the south, and each monitoring location has an unobstructed view of the road to the south

Table 1 presents overall results in terms of L_{den} for each 24-hour period. At location NS1, the calculated L_{den} for each day ranged from 61 to 66 dB. At location NSL2, the L_{den} varied from 52 to 60 dB. The average L_{den} over the entire

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measurement period was 63 dB at NSL1 and 57 dB at NSL2. Generally, the L_{den} at NSL2 was between 6-10 dB lower than that at NSL1.

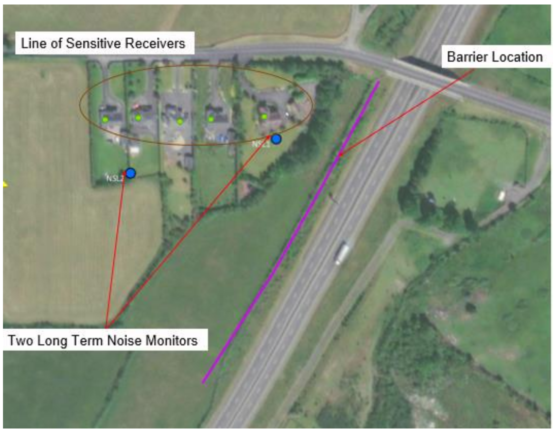

Figure 1. Location of sensitive receivers, previous noise monitoring location, and proposed barrier.

Table 1. Measurement Results in terms of L_{den} for Baseline Assessments

	N1	N2	Difference
Day 1	62	52	10
Day 2	65	57	8
Day 3	62	56	6
Day 4	64	56	8
Day 5	65	58	7
Day 6	64	57	7
Day 7	66	59	7
Day 8	66	60	6
Day 9	64	59	5
Day 10	62	54	8
Day 11	61	54	7
Day 12	62	56	6
Day 13	63	56	7
Day 14	62	54	8

2.2 Condition B – After Noise Barrier Install

In December 2022 a timber noise barrier was installed along the test location beside the roadside edge. The northern end of the barrier ties into the overbridge. The height of the barrier is 3m, the post spacing is 3m and post dimensions are 203 x 113 x 25 UB.

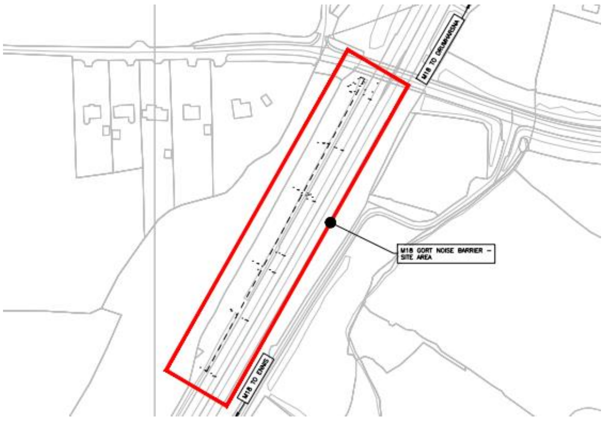

Figure 2. Location of new noise barrier

Following the installation of the noise barrier, noise measurements were again recorded for two weeks at the same location as Condition A. Results are presented in Figure 3 and Table 2. The average difference between Location 1 and Location 2 is 3.6 dB.

The average L_{den} over the entire measurement period was 60.4 dB at NSL1 and 58.2 dB at NSL2. Direct comparison between conditions should be treated with caution, as measurements were taken more than 2 years apart. Note that noise levels at NSL2 increased, while levels at NSL1 have decreased. However, it is noted that the difference between NSL1 and NSL2 have reduced significantly. This would suggest that the installed noise barrier has reduced the noise levels at Location 1.

Table 2. Measurement Results for Condition B.

	N1	N2	Difference
Day 1	52.3	51.1	1.1
Day 2	57.8	54.6	3.2
Day 3	56.5	53.4	3.1
Day 4	58.2	60.8	-2.6
Day 5	60.3	56.1	4.2
Day 6	54.3	51.0	3.3
Day 7	56.9	53.9	3.1
Day 8	59.4	55.2	4.2
Day 9	57.3	52.3	5.1
Day 10	57.2	48.8	8.4
Day 11	56.1	50.5	5.6
Day 12	54.7	51.3	3.4
Day 13	58.3	53.7	4.6
Day 14	61.1	57.2	3.9

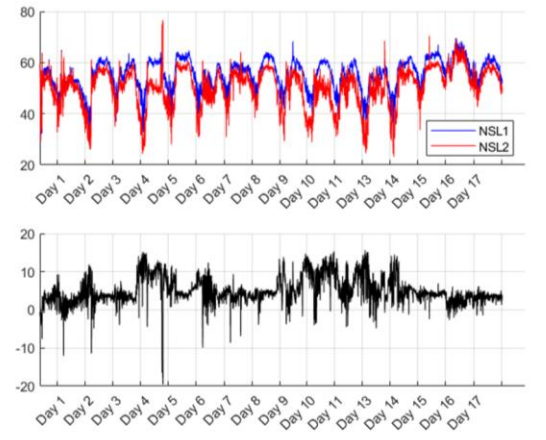

Figure 3. Measurement results for Condition B

2.3 Condition C – After WHIStop Install

In April 2024 a WHIStop diffractor was installed along the test location. The WHIStop, developed by 4Silence, is a lightweight aluminium diffractor that can be mounted on a noise barrier to deflect sound upwards (Figure 4).

Figure 4. The WHIStop diffractor

Measurement results are presented in Figure 5 and Table 3. The average difference between Location 1 and Location 2 is 4.7 dB. The average L_{den} over the entire measurement period was 58.8 dB at NSL1 and 54.5 dB at NSL2. While a slight reduction at Location 1 is observed, it is notable that the difference between NSL1 and NSL2 has increased. Direct comparison should again be treated with caution, as the traffic flow during each period was significantly different, with increased traffic observed during the Condition C measurement period.

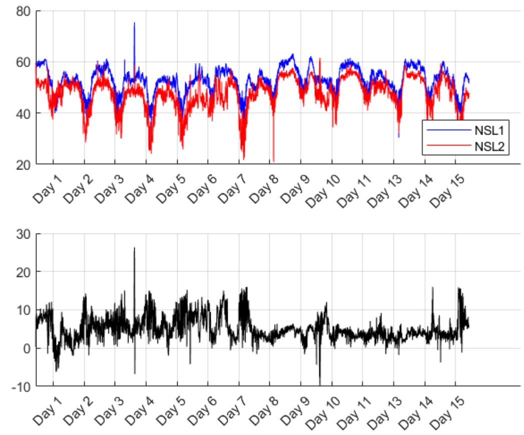

Figure 5. Measurement results for Condition C

Table 3. Measurement Results for Condition C.

	N1	N2	Difference
Day 1	51.9	49.7	2.2
Day 2	55.5	49.7	5.8
Day 3	56.5	47.2	9.3
Day 4	51.4	46.3	5.1
Day 5	52.4	45.6	6.8
Day 6	55.0	49.4	5.5
Day 7	51.9	48.2	3.7
Day 8	58.2	53.6	4.6
Day 9	55.1	50.9	4.2
Day 10	57.4	53.8	3.6
Day 11	53.2	49.7	3.5
Day 12	57.2	53.6	3.6
Day 13	54.3	50.7	3.6
Day 14	51.9	49.7	2.2

3. ACOUSTIC CAMERA MEASUREMENTS

As part of an investigation into the efficacy of the WHIStop addition to the noise barrier, a Head Acoustics Sound Camera was deployed to take measurements at a position close to the barrier.

A suitable position behind the barrier away from the WHIStop installation was established. The Sound Camera was set up according to the dimensions and orientation shown in Figure 6. A recording was made for three minutes. Simultaneously, a video recording using a mobile device was made to record the passage of vehicles on the other side of the barrier. The two videos were then synchronised in post-processing. Recorded files were saved and analysed.

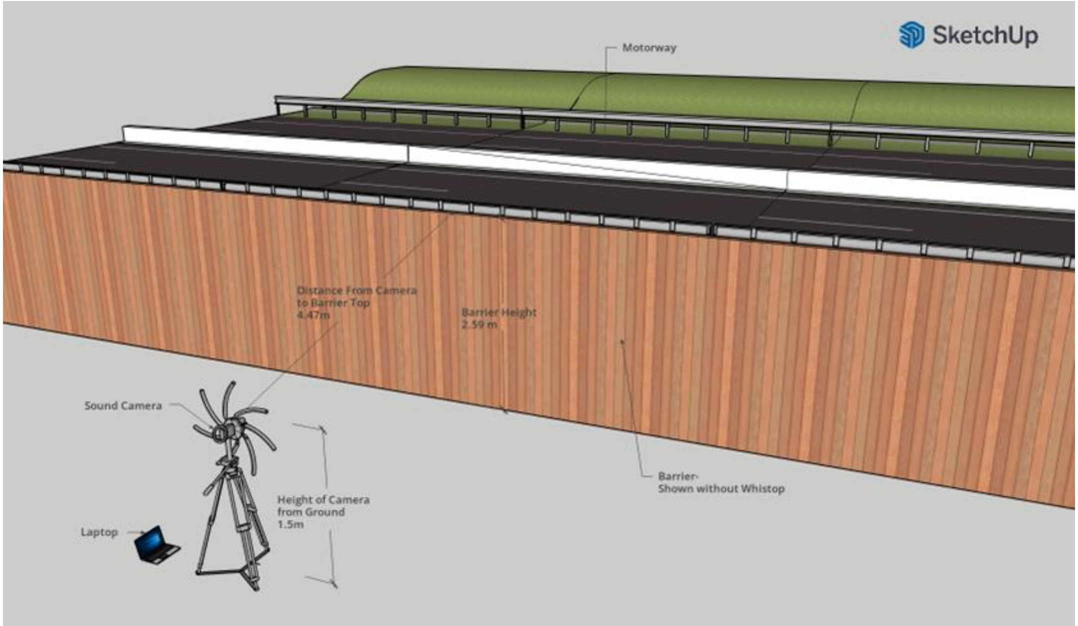

Figure 6. Schematic of Sound Camera test set-up

Figure 7. Photo of Sound Camera on site

3.1 General Test Results

Spot measurements were taken at two locations along the barrier; one at the midpoint of the WHIStop, and another along the midpoint of the barrier with no WHIStop present. Figure 8 presents the A-Weighted equivalent level, averaged over 2 seconds for the duration of the recordings. Results show that the 'No Whistop' data sits a little higher on average than the 'With Whistop' data, with the average difference being approximately 2dB.

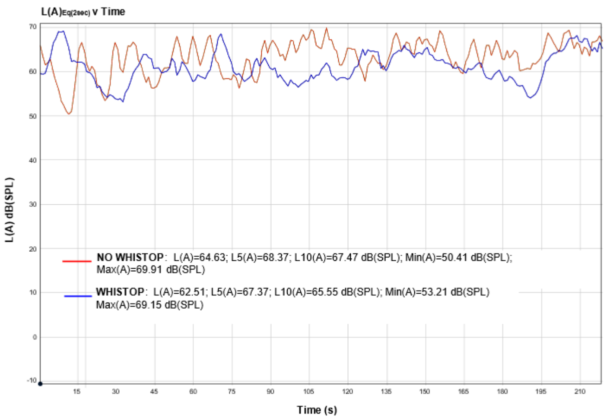

Figure 8. L_{Aeq} with and without WHIStop

Figure 9 shows the results of an FFT analysis of data recorded on site. Results suggest the WHIStop affects the noise spectrum at the receiver position. There is a noticeable difference below the 250 Hz band and also at 10kHz and above. In the WHIStop diffraction process, the lower frequency differences may be due in part to a change in the panel resonance of the barrier due to the physical installation of the WHIStop. The differences observed at high frequencies show evidence of noise diffraction away from the receiver position.

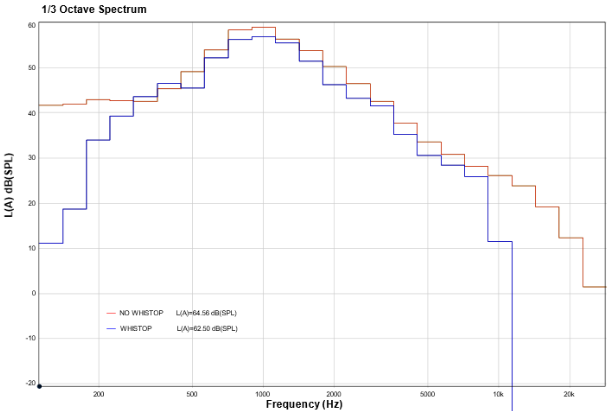

Figure 9. 1/3 Octave Spectra with and without WHIStop

3.2 Acoustic Camera Results

The diffraction induces by the WHIStop is clearly evident in pictures of the diffracting edge from acoustic camera (Figure 10 (a) and (b)).

Figure 10(a). Still frame from Acoustic Camera during car pass-by with no WHIStop

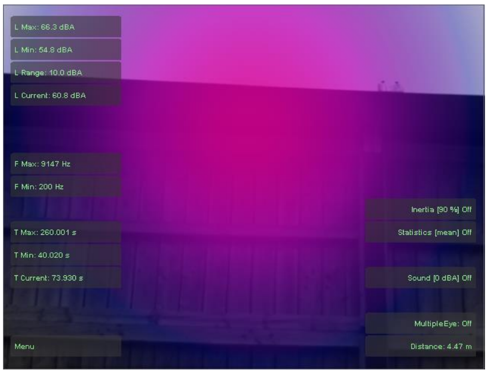

Figure 10(b). Still frame from Acoustic Camera during car pass-by with WHIStop

3.3 Sound Quality

During testing, a distinct flanging effect was noticeable when standing behind the WHIStop. Without the WHIStop, the typical Doppler effect (a downward pitch shift) was clearly heard as vehicles passed on the motorway. However, behind the WHIStop, an approaching vehicle's pitch seemed to drop, but instead of continuing downward after passing, it appeared to rise again. This phenomenon is illustrated in Figure 11 below. In the first case, the Doppler shift is evident as a downward trend in the spectrogram. In contrast, the second image displays a distinct ‘V’ shape, indicating that the pitch increased after the vehicle passed.

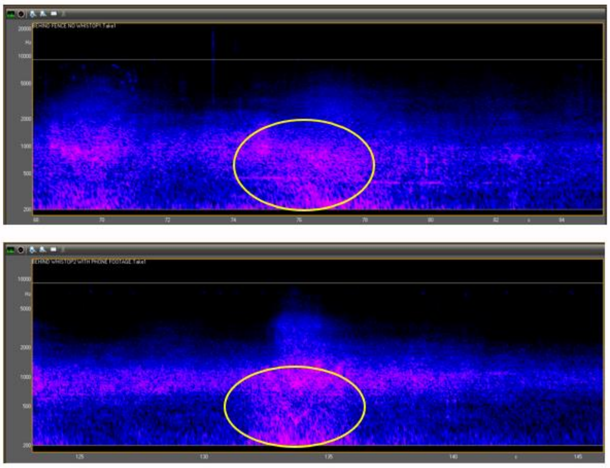

Figure 11. Example of Flanging effect that could be observed on site.

4. MODEL

A noise map for each condition was made to compare predictions with measurements for Condition B and C. Results are reported in Figure 12 and 13. In this case it would seem that the effect of the WHIStop is most noticeable in the shadow zone of the noise barrier, and the noise environment at Location 2 is primarily influenced by noise propagating from other sections of the road.

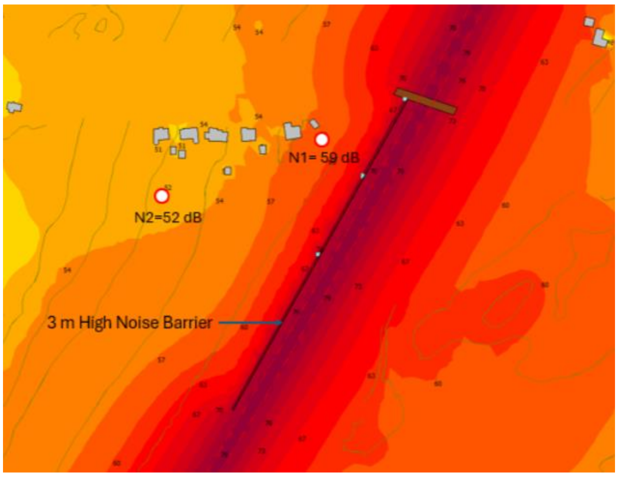

Figure 12. Noise Map of standard noise barrier

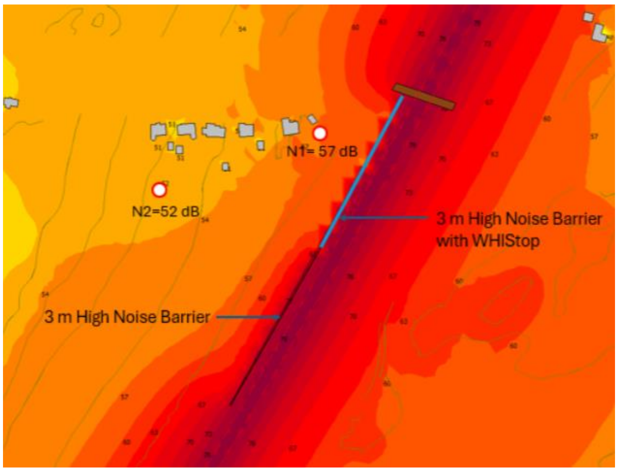

Figure 13. Noise Model of standard noise barrier with WHIStop installed.

5. DISCUSSION

This study aimed to evaluate the effectiveness of the WHIStop diffractor, installed as an addition to an existing 3-meter-high timber noise barrier along a motorway in the west of Ireland. The tests conducted contribute to the expanding body of research in this field [2,3]. The key objectives were to evaluate its impact on noise reduction, specifically the reduction in noise levels and the alterations to the acoustic characteristics of the sound field behind the barrier. Through a combination of noise level measurements, spectral analysis, and acoustic camera data, we observed several notable trends and phenomena that illustrate the potential of the WHIStop in enhancing the acoustic performance of roadside noise barriers.

The results from the baseline noise measurements (without any barrier) indicated relatively high noise levels, Following the installation of the standard noise barrier, a moderate reduction in noise levels was observed at both monitoring locations. Results suggest that the barrier effectively reduced noise exposure for properties located closer to the motorway. But discrepancies in results at sites further away from the barrier might be attributed to changes in traffic flow or other factors over time.

When the WHIStop diffractor was added to the barrier, further changes in noise levels were observed. Although there was a slight reduction in noise at NSL1, it was more significant at NSL2, where the noise level dropped by 3.7 dB compared to the baseline. This was a surprising result which suggest the site is complex, as reduction could not be attributes to the WHIStop alone.

The deployment of Sound Camera provided further insights into the impact of the WHIStop on the noise field behind the barrier. Spot measurements taken at two locations along the barrier revealed that the WHIStop resulted in an average reduction of approximately 2 dB(A). FFT analysis of the recorded sound spectra showed clear differences between the two conditions. The installation of the WHIStop affected the noise spectrum below the 250 Hz range, as well as at frequencies above 10 kHz. The changes at higher frequencies are consistent with diffraction effects, where high-frequency sound waves are deflected away from the receiver position.

Perhaps the most intriguing observation from the acoustic camera and spectrogram analysis was the alteration of the Doppler effect behind the WHIStop. In the baseline condition (no WHIStop), the typical Doppler effect was observed, with a downward pitch shift as vehicles approached, followed by a return to normal pitch after passing. However, with the WHIStop installed, a distinct flanging effect was observed, where the pitch appeared to drop as an approaching vehicle passed but then rose again after the vehicle passed.

5.1 Future Research

The findings from this study indicate that the WHIStop diffractor can enhance the noise mitigation performance of existing barriers by redirecting sound upwards, thereby reducing noise levels behind the barrier. The installation of the WHIStop resulted in measurable noise reductions. The acoustic camera data and spectral analysis further confirmed that the WHIStop alters the sound field in a way that reduces high-frequency noise and changes the characteristics of the sound, particularly in terms of the Doppler shift. This is particular notable in Ireland, as previous research has indicated that more than half of roadside noise barriers in Ireland yield an attenuation of 3dB or less [4].

While the results are promising, it is important to acknowledge the limitations of the study. The measurements taken during the different conditions were not conducted under identical traffic flow conditions, which could influence the results. Future studies should investigate the long-term performance of the WHIStop, assess its effectiveness under different traffic scenarios, and explore its impact on other acoustic phenomena.

Overall, the WHIStop diffractor shows significant potential as a tool for improving the efficacy of noise barriers. It offers an innovative approach to mitigating the impacts of traffic noise in urban and suburban environments.

6. ACKNOWLEDGMENTS

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7. REFERENCES

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