Altissimo Consulting

Field Measurement of Noise Barrier Performance: Reflection Index and Sound Insulation

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Contents

1 Summary

Measurements of noise barrier performance were performed at two sites in Auckland following the methodology specified in EN 1793-5[1] and EN1793-6[2] using the NZ Transport Agency's noise barrier test rig developed in 2018-19 by Altissimo Consulting.

The sound insulation was measured at the following sites:

- Maioro Street (engineered timber barrier)
- McCormick Green – Te Atatu South (concrete barrier)

The sound reflection and the directionality of reflections were also measured at the Te Atatu site. This report presents the results of these measurements and describes the major issues encountered when undertaking these measurements.

The purpose of these tests was to:

- Commission the rig in real world conditions
- Compare results to noise barriers previously measured, and
- Understand the practical limitations of in-situ testing and how such tests may be beneficial to the Transport Agency.

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[1] EN 1793-5:2016 Road traffic noise reducing devices. Test method for determining the acoustic performance. Intrinsic characteristics. In situ values of sound reflection under direct sound field conditions.

[2] EN 1793-6:2012 Road traffic noise reducing devices. Test method for determining the acoustic performance. Intrinsic characteristics. In situ values of airborne sound insulation under direct sound field conditions

2 Maioro Street Barrier – Sound Insulation

The sound insulation of the engineered timber barrier at Maioro Street was tested by the University of Canterbury in 2012[3] using an array of nine microphones. The location of the original testing was not accessible as the rear of the barrier is now a private residence. An alternative location on the same stretch of barrier was identified and tested on 15 June 2019. The locations of these two sites are presented in Figure 1, Figure 2 and Figure 3.

Figure 1: Location of 2012 measurements.

Figure 2: Location of 2019 measurements.

Figure 3: Location of noise barriers tested in 2012 and 2019.

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[3] Bull, J (2012). Measurement of the acoustic performance of traffic noise barriers on Auckland Motorways using prEN1793-6:2011. Acoustics Research Group. University of Canterbury.

2.1 Measurement details

The 2019 measurements were performed by Robin Wareing on 18 June 2019. Details of the measurements are presented in Table 1. The test arrangement is shown in Figure 4 and Figure 5.

Throughout the testing the traffic on Maioro Street was busy but remained flowing. There were no significant external noise sources observed during the testing of the barrier. No obvious gaps or damage to the barrier was noted.

Table 1: Maioro Street Noise Barrier – measurement details

Date	18/06/2019	
Nearest Road	Maioro Street	
GPS location	36°51'25.6"S 174°38'59.8"E	
Barrier construction	Horizontal engineered timber panels with steel posts	
Condition	Weathered but good condition	
Height	3 m	
Low frequency limit (Barrier height)	315 Hz	
Barrier thickness	Panels: 50 mm Posts: 200 mm (steel “I”-beam)	
Weather conditions	Wind	< 5 km/hr
	Temperature	14° C
	Precipitation	None
Equipment	Transport Agency noise barrier test rig	
Operator	Robin Wareing	
Distance from barrier to microphone array	0.25 m	
Distance from barrier to loudspeaker	1.0 m	
Height of center of measurement point	1.5 m	

Figure 4: Microphone array and loudspeaker during sound insulation tests at Maioro Street.

Figure 5: Microphone array during sound insulation tests at Maioro Street.

2.2 Results

The barrier is built from engineered timber panels between steel posts. The sound insulation of the barrier elements is presented in Figure 6 below, along with the 2012 results for comparison.

The barrier height of 3 meters yields a low frequency limit of 315 Hz for the 2019 and 2012 measurements (based on Figure 13 of EN 1793-5). The sound insulation values below this low frequency limit are grey or black in Figure 6 below.

The variations in the measured sound insulation index between 2012 and 2019 may be the result of:

- The different location on the barrier
- The different measurement setup and equipment

The single number classifications (SI) for this noise barrier is presented below.

Table 2: Maioro Street Noise Barrier – single number sound insulation

Barrier component	Sound Insulation (SI)	
	2012 results	2019 results
Panel	36	39
Post	35	39

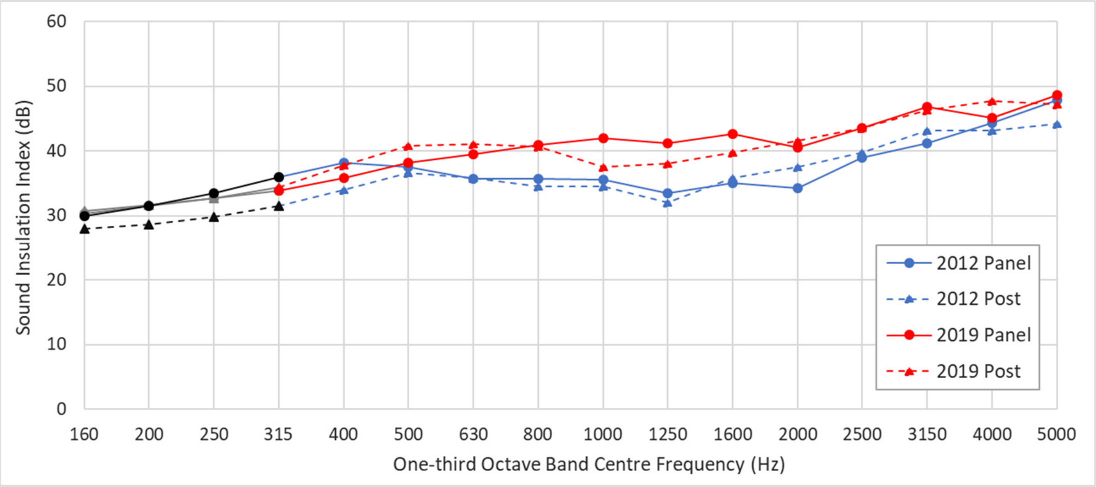

Figure 6: Sound insulation of Maioro Street barrier.

The signal-to-noise ratio for the 2012 and 2019 results are presented in Figure 7. In all the third octave bands measured the signal-to-noise ratio is greater than 10 dB for the 2019 measurements, as required by EN 1793-6. No limitations are placed on the results by the signal-to-noise ratio.

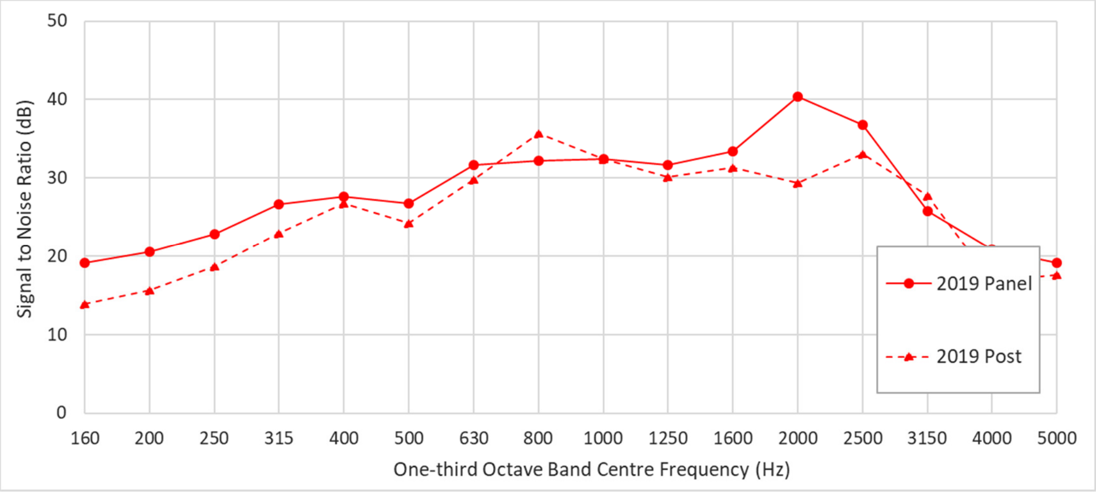

Figure 7: Signal-to-noise ratio of sound insulation measurements of Maioro Street barrier.

3 Te Atatu South, McCormick Green – Sound Insulation

The sound insulation of the concrete noise barrier located at McCormick Green (Te Atatu South) was measured on 18 June 2019. The measurement location is shown in Figure 8.

Figure 8: Location of McCormick Green noise barrier.

3.1 Measurement details

Details of the measurements are presented in Table 3. The test arrangement is shown in Figure 9 to Figure 12.

Throughout the testing the traffic on SH16 was busy but remained flowing. There were no significant external noise sources during the testing of the barrier.

No damage to the barrier was noted. There was audible noise leakage through the joint between the concrete panels and the steel posts.

Table 3: McCormick Green Noise Barrier – measurement details

Date	18/06/2019	
Nearest Road	SH 16 – North West Motorway	
GPS location	36°51'25.6"S 174°38'59.8"E	
Barrier construction	Horizontal concrete panels with steel posts	
Condition	Near new	
Height	4.2m	
Low frequency limit (Barrier height)	160 Hz	
Barrier thickness	Panel: 150 mm Post: 300 mm (steel "S"-beam)	
Equipment	Transport Agency noise barrier test rig	
Operator	Robin Wareing	
Weather conditions during testing	Wind	7 – 15 km/h
	Temperature	13° – 14° C
	Precipitation	None
Distance from barrier to microphone array	0.25 m	
Distance from barrier to loudspeaker	1.25 m	
Height of center of measurement point	2 m	

Figure 9: Loudspeaker during sound transmission measurements at McCormick Green.

Figure 10: Microphone array during sound insulation and reflection index of posts at McCormick Green.

Figure 11: Microphone array during sound insulation of concrete panels at McCormick Green.

Figure 12: Microphone array and loudspeaker during free-field measurements at McCormick Green.

3.2 Results

The barrier is constructed from concrete panels between steel posts. The sound insulation of both elements is presented in Figure 13. The barrier height of 4 meters yields a low frequency limit of 160 Hz.

The sound insulation results are compared with those of a similar concrete barrier at that was tested in 2012[3]. The single number classifications (SI) for both noise barriers are presented in Table 4.

Table 4: McCormick Green Noise Barrier – single number sound insulation

Barrier component	Sound Insulation (SI)	
	2012 results	2019 results
Panel	65	44
Post	61	61

The sound insulation results from the 2012 and 2019 measurements are similar for the post measurements. The panel results deviate widely between the 2012 and 2019 measurements. This is likely due to the following:

- The different construction of the barrier
- The different background noise level
- The low signal to noise ratio
- The different measurement system

The signal-to-noise ratio is shown in Figure 14. The 2019 signal-to-noise ratio is below 10 dB for the frequency bands below 1,000 Hz for the panel results, and around 0 dB for the post results. The signal to noise ratio in the 2019 measurements is greater than that in the 2012 measurements, due to the use of the exponential swept sine excitation.

The low signal-to-noise ratio for both the 2012 and 2019 measurements indicates that the measured values are not reliable across much of the frequency range. The low signal-to-noise ratio is likely to be the main reason for the deviation between the 2012 and 2019 results. The poor signal-to-noise ratio means that the current results can be considered as a lower limit of performance. The true barrier performance will be better that current results.

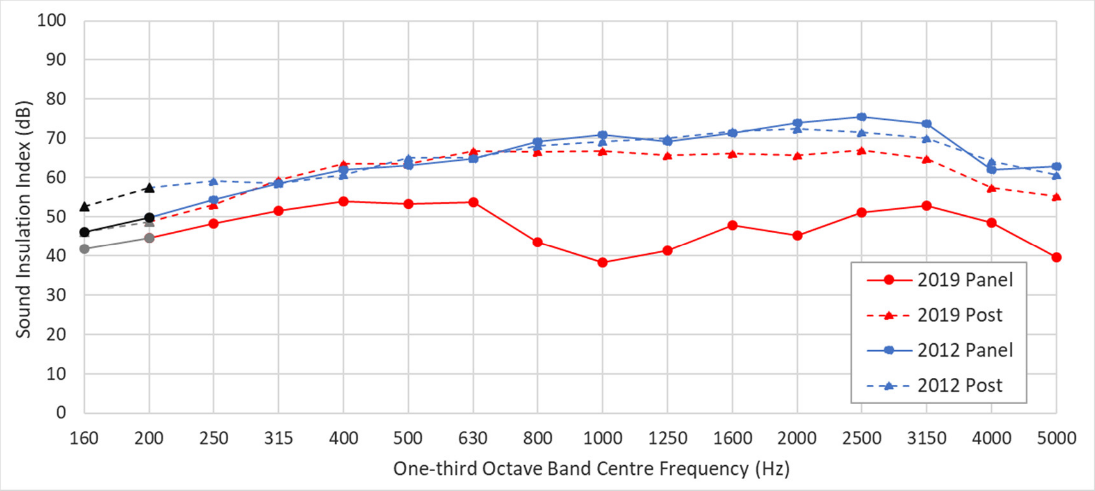

Figure 13: Sound insulation of McCormick Green barrier.

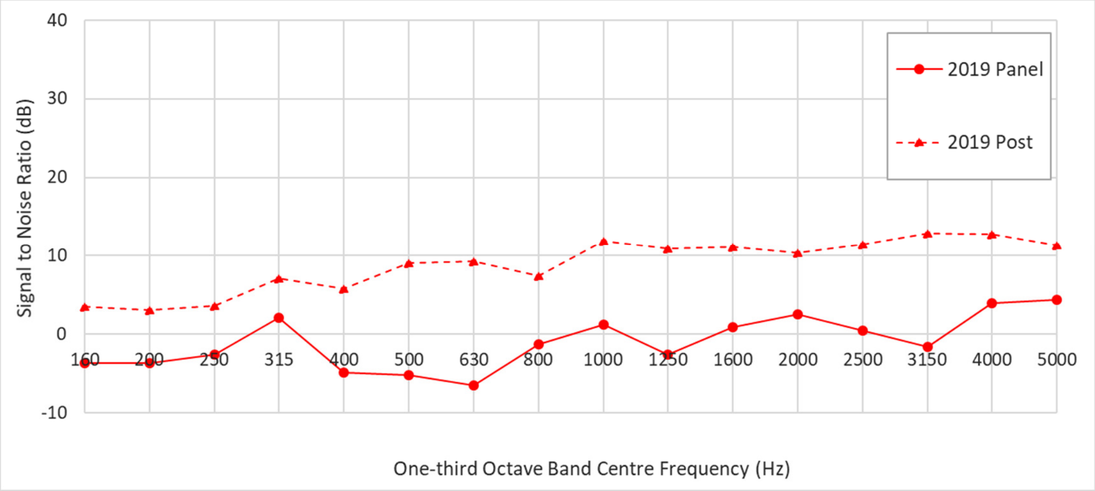

Figure 14: Signal-to-noise ration of sound insulation measurements of McCormick Green barrier.

3.3 Recommendations

The current software does not calculate the sound insulation in the field. This should be updated to allow immediate calculation of the sound insulation. Any unusual or unexpected results, such as the panel results presented above, could be repeated to ensure they are not due to errors or extraneous noise.

4 Te Atatu South, McCormick Green – Sound Reflection Index

The sound reflection index (RI) of the concrete barrier tested in the previous section was evaluated at the same time using the procedure described in EN 1793-5.

The test was performed on the park side of the barrier due to space limitations on the road facing side. Apart from the paint, both sides of the barrier are identical.

The sound reflection index was measured for the barrier panel and the steel post. The measurement setup is shown in Figure 15.

Figure 15: Microphone array and loudspeaker in place for performing reflection index

4.1 Measurement details

The measurements were performed by Robin Wareing on 18 June 2019, further measurement details are presented in Table 5.

Throughout the testing the traffic on SH16 was busy but remained flowing. There were no significant external noise sources noted during the testing of the barrier.

Table 5: McCormick Green Noise Barrier – measurement details

Date	18/06/2019	
Nearest Road	SH 16 – North West Motorway	
GPS location	36°51'25.6"S 174°38'59.8"E	
Barrier construction	Concrete panels with steel posts	
Condition	Near new	
Height	4.2m	
Weather conditions	Wind	< 5 km/hr
	Temperature	14°C
	Precipitation	None
Equipment	Transport Agency barrier test rig	
Operator	Robin Wareing	
Weather conditions during testing	Wind	7 – 15 km/h
	Temperature	13° – 14° C
	Precipitation	None
Distance from barrier to microphone array	0.25 m	
Distance from barrier to loudspeaker	1.25 m	
Height of center of measurement point	2 m	

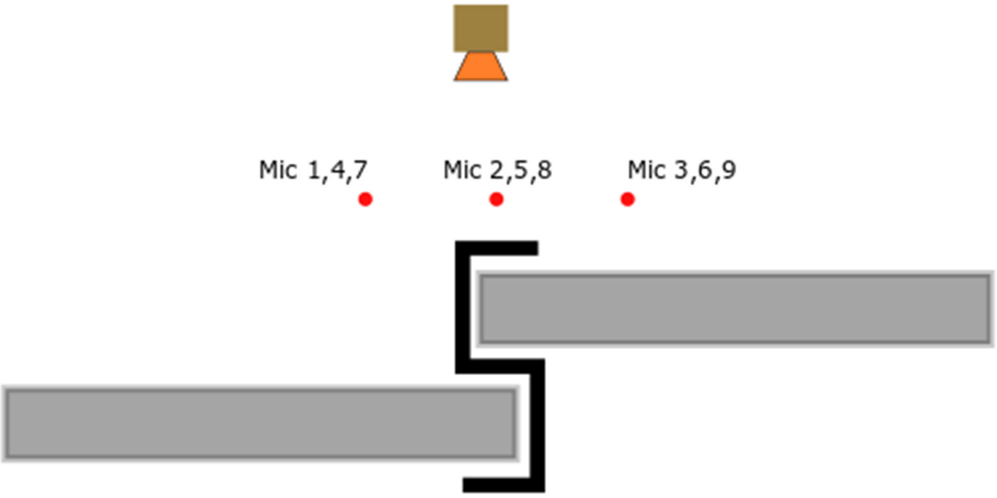

Figure 16: Plan view of arrangement of barrier test rig for measuring barrier post.

4.2 Results

The sound reflection index results from the panel and post are presented in Figure 17. The lower levels at the post are likely due to the decreased reflections from the stepped section of wall. The measured reflection index is lower than expected from a concrete wall, this may be due to the rough surface of the panel.

Table 6: McCormick Green Noise Barrier – single number sound insulation

Barrier component	Sound Reflection (DL_{RI})
Panel	3.9
Post	2.5

The signal-to-noise ratio is greater than 10 dB across the frequency range measured; this indicates that the measurements are not altered by background noise.

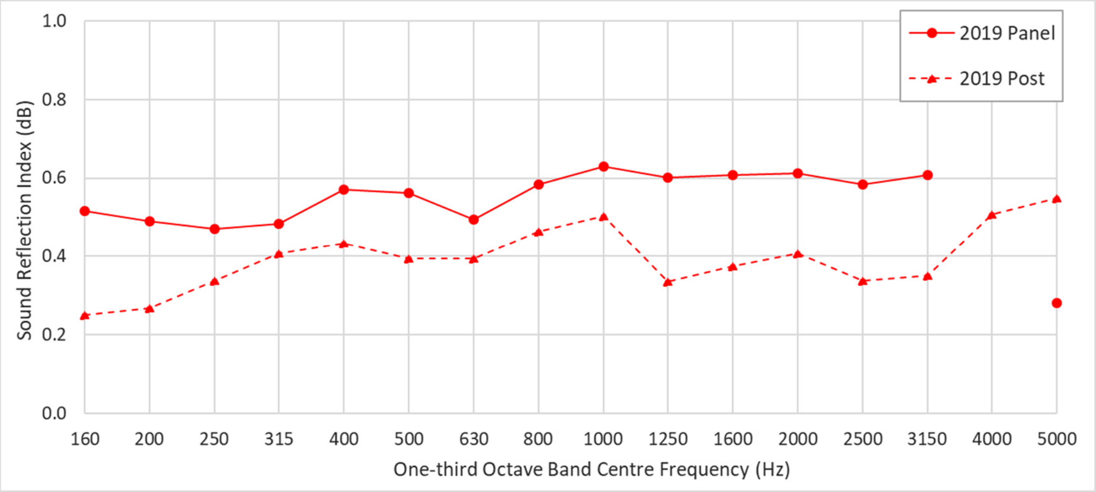

Figure 17: Sound reflection index of McCormick Green barrier.

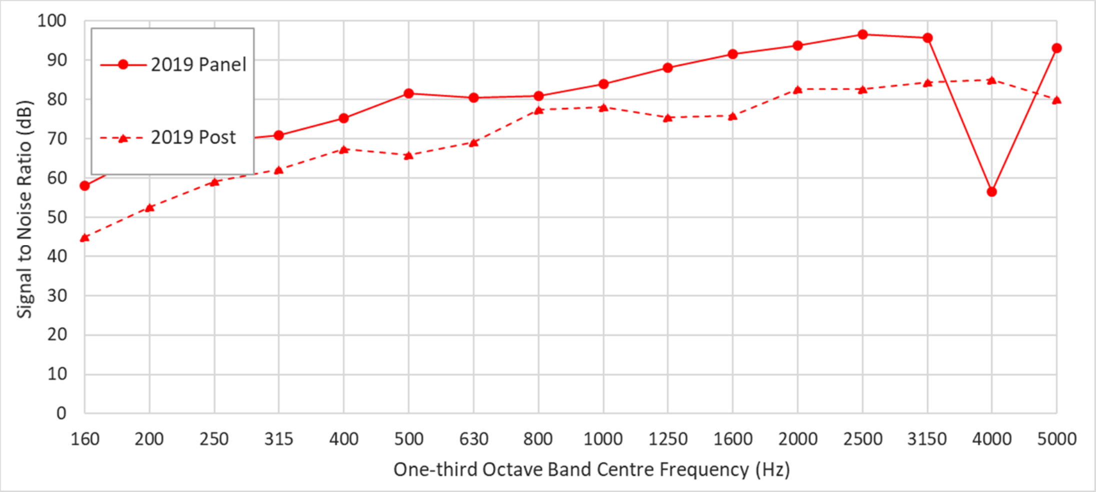

Figure 18: Signal-to-noise ratio for sound reflection index of McCormick Green barrier.

4.3 Effect of step on results

There was no observable difference in the reflection coefficient for each microphone in relation to the step. The reflection index as described in EN 1793-5 is not a suitable measure of the directionality of the reflections off the panel surface. The relationship between the direction of the reflections could not be reliably resolved from the reflection index.

The step shape was evident in the received impulse responses for the post. The increased path length can be clearly seen in the increased time of flight in Figure 19.

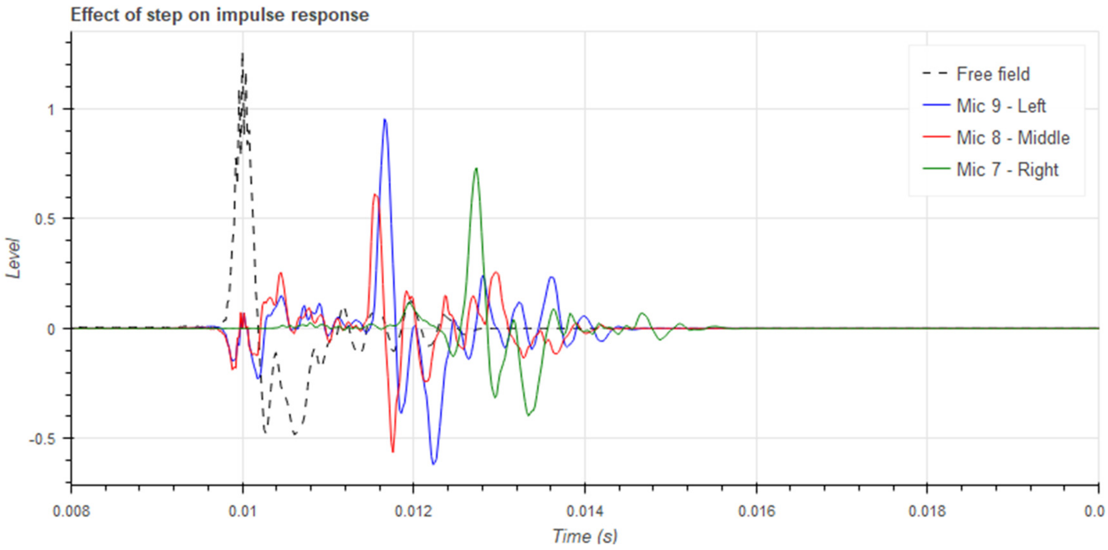

Figure 19: Variation in arrival time of reflected signal due to the step.

Methods for evaluating the directionality of reflections from a panel system require significant development, testing, and validation. Additional testing should be performed to validate the measured reflection coefficient, ideally a collection of surfaces with known reflectivity coefficients should be tested.

5 Modified Reflection Measurement

An alternative test was performed on the step section of the McCormick Green noise barrier to evaluate the capacity of the barrier test rig to measure the directionality of the reflections. This directionality is of interest as a number of barriers have been developed with complex surface patterns. The effect of these surface patterns on the reflected sound is not well understood.

This alternative test was performed by offsetting the array, to evaluate if gross variations in the direction of reflections could be evaluated. A step was chosen as is would result in significant variations in the directionallity of the reflections. If this step could be resolved in the reflection index values it would indicate that the test rig may be suitable for evaluating the directonality of noise barriers.

The test layout is illustrated in Figure 20.

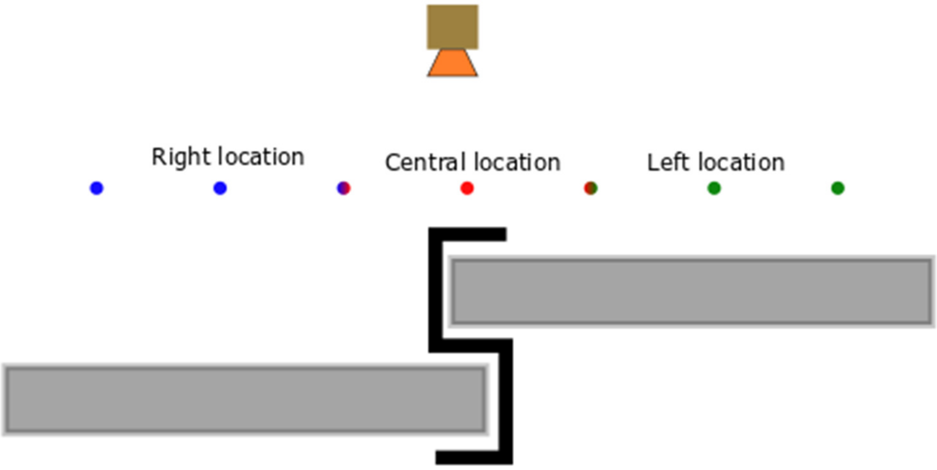

Figure 20: Modified layout for evaluation of reflection directionality

The speaker was fixed in the central location and the barrier test rig was shifted to the left and right. The microphones were placed to overlap at on either side.

5.1 Results

The time delay shown in Section 4.3 was also seen in the altered measurement, as illustrated in Figure 21 and Figure 22. This time delay is due to the increased path length for reflections off the rear panel.

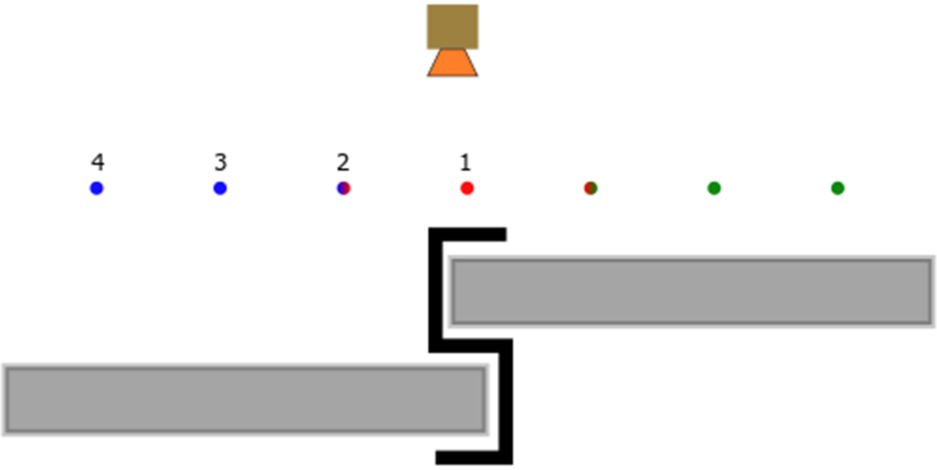

Figure 21: Microphone reference numbers for modified reflection test

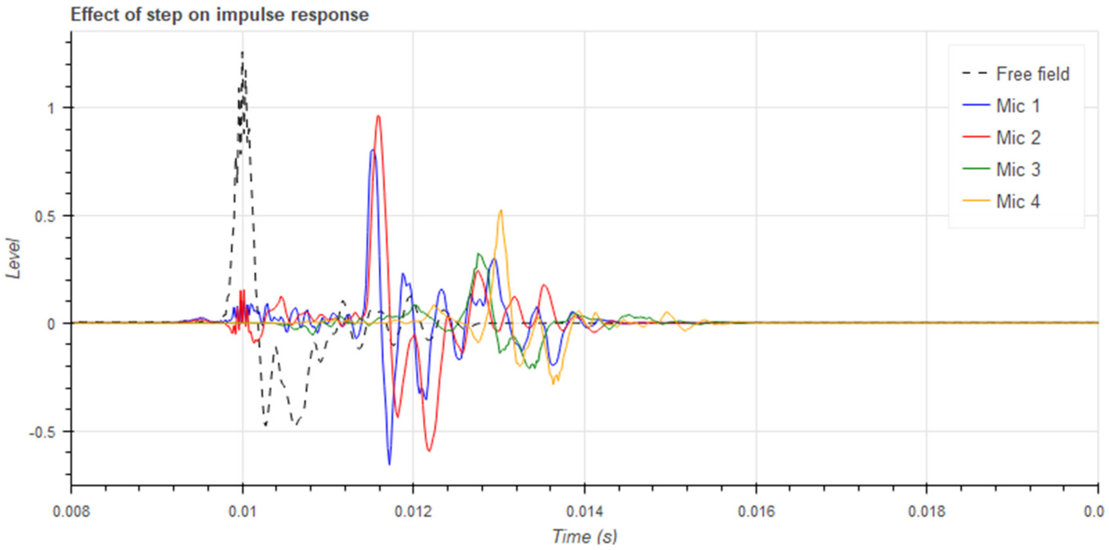

Figure 22: Time delay for offset microphones

When the reflection coefficient for the outer measurements were performed the values were significantly higher than one. This is not a valid value and is likely caused by the following reasons:

- Ground reflections may be affecting the impulse response
- The alignment was very difficult to maintain between the free-field and reflection tests
- The test rig's batteries were becoming unreliable by this point in the testing (see Section 6.3) and this is likely to have altered the signal between the free-field and reflection measurements
- The directionality of the speaker has not been fully qualified and may be affecting the wider measurement locations

5.2 Evaluation of method

This modification to the standard method did not provide useful information on the directionality of the reflected signal. Significant additional testing would be required on standardised test samples to create a functional measurement procedure. In addition, an alternative array would be required to improve the alignment between the 27 microphone positions.

6 Measurement Challenges

Noise barrier measurements were planned at the following locations:

- Maioro Street
- Kirkbride Road
- Ellerslie (SH1)
- SH18 – Upper Harbour Motorway

Only Maioro Street was measured due to traffic management requirements and access difficulties. This section details the major difficulties faced and lessons learned during this testing.

6.1 Traffic management

The proposed sites were all on Level 3 roads within the Auckland Motorway network, this requires traffic management for operator safety. The measurements require an operator to be working within the shoulder of these roads, outside of a vehicle.

According to COPPTM, if measurements can be completed within 1 hour they are classified as "semi-static" closures, and in some cases an allowance may be made by the Road Controlling Authority to allow works that take slightly longer than 1 hour. COPPTM specifies a single Truck Mounted Attenuator (TMA) as a shadow vehicle and an Advance Warning Variable Message Sign (AWVMS). On the Auckland Motorways it is typically expected that the AWVMS is replaced with an additional TMA unit.

The sound insulation measurements can be performed relatively quickly and may be practical to undertake as "semi-static" works. In order to perform these measurements correctly within the 1-hour time limit the measurement system would need to be significantly more robust and quicker to set-up than the current system. Two staff would be required to access both sides of the test site.

The reflection measurements would typically take more than an hour to set-up and perform. Undertaking these as "semi-static" works requires specific approval from the Road Controlling Authority. Static works require installation of signage, cones, and would typically require a lane closure.

As the measurements were likely to extend over the 1-hour time limit the requirements specified by the TMC/RCA changed several times during the project planning. Furthermore, the requirements for any works with a single vehicle (e.g. inspections) became significantly stricter. Eventually the only acceptable options for performing these works were:

- A full closure of all lanes in the direction being tested
- Use of Teaki (mobile barrier)

These options were prohibitively complex for the current measurements. In future reflection index measurements should only be planned where no access to motorways are required or be timed to coincide with a full closure for other works. Sound insulation measurements could be performed as 'mobile works' which require significantly less traffic management.

6.2 Access

Access to the roadside of the barrier is typically straight-forward if traffic management is in place, but the rear of the barriers is often on private property which can make access difficult. Typically the measurements need to be performed at night for traffic management purposes, which further complicates access to private property.

Some sites have public access to both the front and rear of the barrier, the two sites tested were chosen for this reason. A trail site in Hamilton was also investigated but access to the front of the barrier was not feasible due to high fencing, private property, and significant plant growth.

When considering access to barriers it should be noted that the roadside of these barriers is often densely planted. Manoeuvring the measurement system or speaker into place through this vegetation can be very challenging or impossible.

All testing should be preceded by a site visit to assess access to the front and rear of the barrier.

6.3 Power supplies

When adjacent to the road the measurement system can operated using a vehicle's 12-volt supply. The following components need power in order to undertake the measurements:

- Laptop
- Amplifier
- National Instruments data acquisition equipment

When operating the system further from a vehicle a 12-volt battery pack must be used. During this round of testing the CPX systems batteries were utilised, but these were not fully charged when the measurements were started. The high current draw from the amplifier caused the battery voltage to drop below the level required to operate the data acquisition system, causing the data acquisition system to shut down.

If the test rig is to be used for measurements where a reliable power supply (e.g. car 12V supply) is not available, the battery supplying the amplifier should be independent from the rest of the measurement system.

7 Conclusions

The noise barrier test rig allows rapid, simple, and reliable measurements of the sound insulation of noise barriers. The sound insulation measurements can be performed as semi-static works, dramatically reducing the traffic management requirements.

The exponential swept sine excitation provides very high signal-to-noise ratios, these signal-to-noise ratios are significantly higher than the MLS used in the 2012 measurements. The 2012 and 2019 measurement systems are not suitable for measuring the sound insulation of the concrete barrier. If concrete barriers are to be tested a higher excitation signal level will be required, this is possible with the current system.

The current system is not suitable for performing in-situ sound reflection testing, due to the long setup and testing time. In addition, the precise alignment requirements make this test difficult to execute in-situ. The system is suitable for performing reflection index testing in locations where traffic management is not required.

The current system is not suitable for undertaking modified reflection measurements of the directionality of the barrier. Further testing and development would be required to modify the test system to appropriately perform these measurements.