UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND
College of Engineering

Acoustics Research Group
Department of Mechanical Engineering

REPORT

Number: **252**

Issue: **1**

Report Date: **27-Nov-2012**

Measurement of the Acoustic Performance of Traffic Noise Barriers on Auckland Motorways Using prEN1793-6:2011

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Acoustics Research Group	Report number 252	Issue date 27/11/2012

TITLE AND SUBTITLE Measurement of the Acoustic Performance of Traffic Noise Barriers on Auckland Motorways Using prEN1793-6:2011	Version No. 1 Departmental code
PREPARED BY John Bull	Contract/Grant No.

SUPPLEMENTARY NOTES

ABSTRACT

The airborne sound insulation index of eight traffic noise barriers in the Auckland area were measured and the practical aspects of the field work documented.

KEYWORDS

Traffic noise barriers, NZTA, Airborne sound insulation

AVAILABILITY ☒ For release to client only ☐ For Departmental use only ☐ For general release	No of pages 91

SIGNATURES

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☐ Released by: John Pearse

Summary

The airborne sound insulation of eight traffic noise barriers has been measured in accordance with the draft European standard prEN1793-6:2011. The barrier types included concrete, acrylic, engineered timber, plywood and slatted timber. The concrete barriers were found to have the highest values of airborne sound insulation, which was expected due to their high mass and absence of air gaps. The acrylic barrier performed slightly better than the engineered timber and plywood barriers, however when an air gap between the concrete crash barrier and acrylic panel was included in the calculation, the airborne sound insulation dropped significantly. The slatted timber barrier had the lowest values of airborne sound insulation, due to the presence of multiple joints between the timber planks. Individual test reports have been prepared for each traffic noise barrier and included as appendices.

The practical aspects associated with making measurements to EN1793-6 on New Zealand State highways have been documented. These include the time, safety and access requirements of the three different types of sites encountered (residential, road-inspection and semi-static closure). Residential sites could be accessed from local roads. Road inspection sites required access from the motorway, with work being conducted at least 5 metres away from the live traffic lane. Truck mounted attenuators were used at the semi-static closure sites and the duration of the tests was limited to 30 minutes. Issues raised from this work will help to inform further developments of EN1793-6.

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1 Introduction

1.1 Motivation

The University of Canterbury has developed an in-situ measurement system to quantify the airborne sound insulation of traffic noise barriers. The system is designed to meet the draft European standard EN1793-6:2011 *Road traffic noise reducing devices - Test method for determining the acoustic performance - Part 6: Intrinsic characteristics - In situ values of airborne sound insulation under direct sound field conditions*, (CEN, 2011).

The NZ Transport Agency (NZTA) is interested in the possible use of EN1793-6 for measuring the acoustic performance of traffic noise barriers along the New Zealand State highway network. Preliminary tests were conducted on eight traffic noise barriers in the Auckland area to investigate the practical aspects associated with using EN1793-6 in New Zealand, as well as providing performance data on individual traffic noise barriers. The work was undertaken during the week of 22 October 2012.

1.2 Test Standard

EN1793-6 describes a method to measure the airborne sound insulation index of a noise barrier, and thus the effectiveness of the barrier at blocking the direct sound path. The standard does not take into consideration the diffracted sound path that travels over the top of the barrier, although this may be measured using CEN/TS 1793-4 (CEN, 2003) with a slightly different equipment layout.

The attractiveness of the test method is that it allows the acoustic performance of traffic noise barriers to be quantified in situ. Recently constructed barriers can be tested to ensure that they meet the design specifications, and the performance of existing traffic noise barriers can be monitored over time. The test method may also be used by manufacturers to provide performance data of their barriers without the need for laboratory testing.

A summary of the test method is given in Appendix A.

1.3 Report Layout

This report contains details of the practical aspects associated with making measurements to EN1793-6 on New Zealand State highways; including details of the access, safety and time requirements. Test reports for each of the eight traffic noise barriers have been prepared and attached as appendices. Comparisons of the acoustic performance of the different traffic noise barriers are made.

2 Measurements Performed

Eight of the original thirteen identified traffic noise barriers were tested during the week of 22 October 2012 by John Bull and Ryan McKinlay. A summary of the measurements made is shown in Table 1.

Table 1 Auckland test sites

Name	*Material*	*Measurements*
Northern Busway	plywood	2x panels
Maioro Street (Concrete)	concrete	1x panel 1x post
Greenhithe	engineered timber	2x panels 2x posts
Hobsonville	plywood	2x panels
Green Lane	concrete	1x panel 1x post
St Marys Bay	acrylic	2x panels 1x post
Kingsland Cycleway	timber	2x panels 1x post
Maioro Street (Engineered Timber)	engineered timber	2x panels 2x posts
Takanini	concrete	none, semi-static closure needed
Mount Roskill	concrete	none, semi-static closure needed
Mangere	concrete	none, semi-static closure needed
Maioro Street (Plywood)	plywood	none, limited space
SH1/SH20	timber	none, limited time

The time required at each test site was longer than initially anticipated. As such measurements were only made at eight of the original thirteen sites, and fewer measurements were conducted at each test site so that as many sites could be visited as possible.

3 Practical Aspects

Being an in situ test method, the location of the traffic noise barrier dictates the safety, access and time requirements associated with each test.

3.1 Measurement Equipment

The measurement equipment was packed into two Pelican travel cases for protection during transport. The loudspeaker and tripods were packaged in cardboard boxes for transport between Christchurch and Auckland. Figure 1 shows the measurement equipment laid out on the ground at a test site. Further details of the measurement equipment are given in Appendix A.

Figure 1 Measurement equipment

3.2 Test Site Classification

The traffic noise barrier test sites were classified as either residential, road inspection, or semi-static closure sites based on the risk present to the operators. Table 2 lists the test sites visited during the week of 22 October 2012, with their classification.

3.2.1 Residential Sites

Sites where the operators were able to access both sides of the barrier on foot from local roads were classified as residential sites. Three test sites were classified as residential sites, these were Maioro Street (concrete), Maioro Street (engineered timber) and Kingsland Cycleway. An example of a residential site is shown in Figure 2.

Table 2 Classification of traffic noise barrier test sites

Name	*Site Classification*
Northern Busway	Road Inspection
Maioro Street (Concrete)	Residential
Greenhithe	Road Inspection
Hobsonville	Road Inspection
Green Lane	Semi-static Closure
St Marys Bay	Semi-static Closure
Kingsland Cycleway	Residential
Maioro Street (Engineered Timber)	Residential

3.2.2 Road Inspection Sites

Sites where the operators were able to park and work more than 5 metres away from the live lane, with good protection being provided by crash barriers or road layout, were classified as road inspection test sites. All of these sites involved Level 3 roads (high volume, high speed multi-lane roads and motorways) and the operators were only permitted to work outside of peak traffic flows (9am to 3pm and 7pm to 6am). The Auckland Motorway Alliance (AMA) traffic management plan (TMP) for generic inspections was used (TMP-18261), with the Joint Transport Operations Centre (JTOC) being notified at the beginning and end of each testing session.

Three test sites were classified as road inspection sites, these were Northern Busway, Greenhithe and Hobsonville. An example of a road inspection site is shown in Figure 3.

3.2.3 Semi-static Closure Sites

Sites where the operators had to work within 5 metres of the live lane and/or were not adequately protected by crash barriers or road layout were classified as semi-static closure sites. These sites required the use of truck mounted attenuators (TMAs) to protect the operators. The TMAs were only permitted to stop for 30 minutes at a time. Two test sites were classified as semi-static closure sites, these were Green Lane and St Marys Bay. An example of a semi-static closure site is shown in Figure 4.

3.3 Health and Safety Considerations

The two operators attended the AMA Motorway Inspection Course on Tuesday, 23 October 2012. This allowed them to perform tests at road inspection sites and provided them with the skills to operate safely in the semi-static closure sites. The training course was held at the AMA office in Green Lane and took eight hours to complete, however it is understood that this was the last time that the course would be run by the AMA. Future courses will be coordinated centrally by the NZTA.

The AMA traffic management plan (TMP) for generic inspections was used (TMP-18261) for the road inspection sites, refer to Appendix J for a copy of TMP-18261.

The operators were required to wear:

- high visibility vest
- hard hat
- lace up steel cap safety boots
- safety glasses

The work vehicle was required to have:

- a rotating amber beacon
- working hazard lights
- "ROAD INSPECTION" sign

When accessing a road inspection site the following actions are required:

- advise JTOC of the location and duration of the inspection
- review the TMP, including hazards and contingency plans
- ensure that vehicle safety equipment is installed and working, and that personal safety equipment is easily accessible
- perform drive by site inspection to check site access and hazards
- enter and leave the site in the manner outlined in the TMP
- advise JTOC once the work has been completed

3.4 Time and Access Requirements

The time required to conduct the measurements depended on the ease of access to the specific site, Table 3 gives the approximate duration of each measurement activity.

Table 3 Approximate time required to conduct a measurement

Activity	*Time Required*
setup	60 minutes
free-field/panel/post measurement	15 minutes each
pack up	30 minutes

3.4.1 Residential Sites

Testing at a residential site such as Kingsland Cycleway required the shortest time to setup, conduct measurements and pack up. This was due to the easy site access, where the work vehicle could be parked within 20 metres of the work area and both sides of the barrier could be accessed by foot within a short distance.

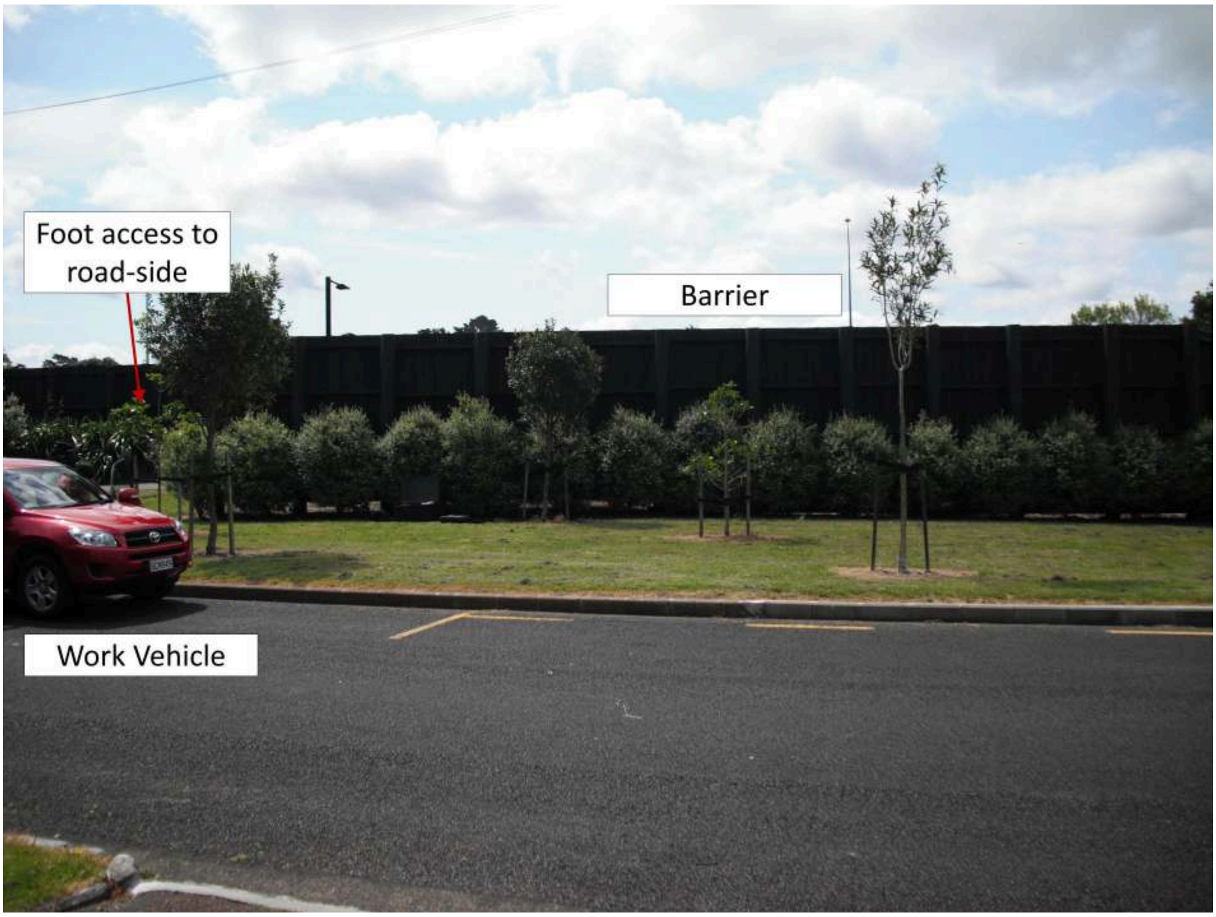

Figure 2 Residential site layout, Kingsland Cycleway

3.4.2 Road Inspection Sites

Testing at a road inspection site such as Greenhithe required a longer time at the test site. The need to conduct an initial assessment of the site during a drive by and the difficulty of reaching the rear-side of the barrier by foot meant that it took longer to setup the measurement. The equipment had to be carried to the rear-side of the barrier through thick vegetation, adding to the setup time. Figure 3 shows the Greenhithe test site.

3.4.3 Semi-static Closure Sites

Testing at a semi-static closure site such as St Marys Bay required additional time during the setup stage to negotiate with the Site Traffic Management Supervisor (STMS) and TMA drivers. The barrier was initially assessed by the operators and any health and safety concerns raised with the STMS before beginning the setup. Once the measurement equipment was setup on the rear-side of the barrier, one of the operators met the TMAs at a pre-arranged location with the work vehicle and loudspeaker. They then travelled to the road-side of the barrier, parking safely and setting up the loudspeaker for the first measurement.

After the barrier measurements were complete, the operator travelled to the rear-side of the barrier with the loudspeaker to conduct the free-field measurement. Figure 4 shows the St Marys Bay test site.

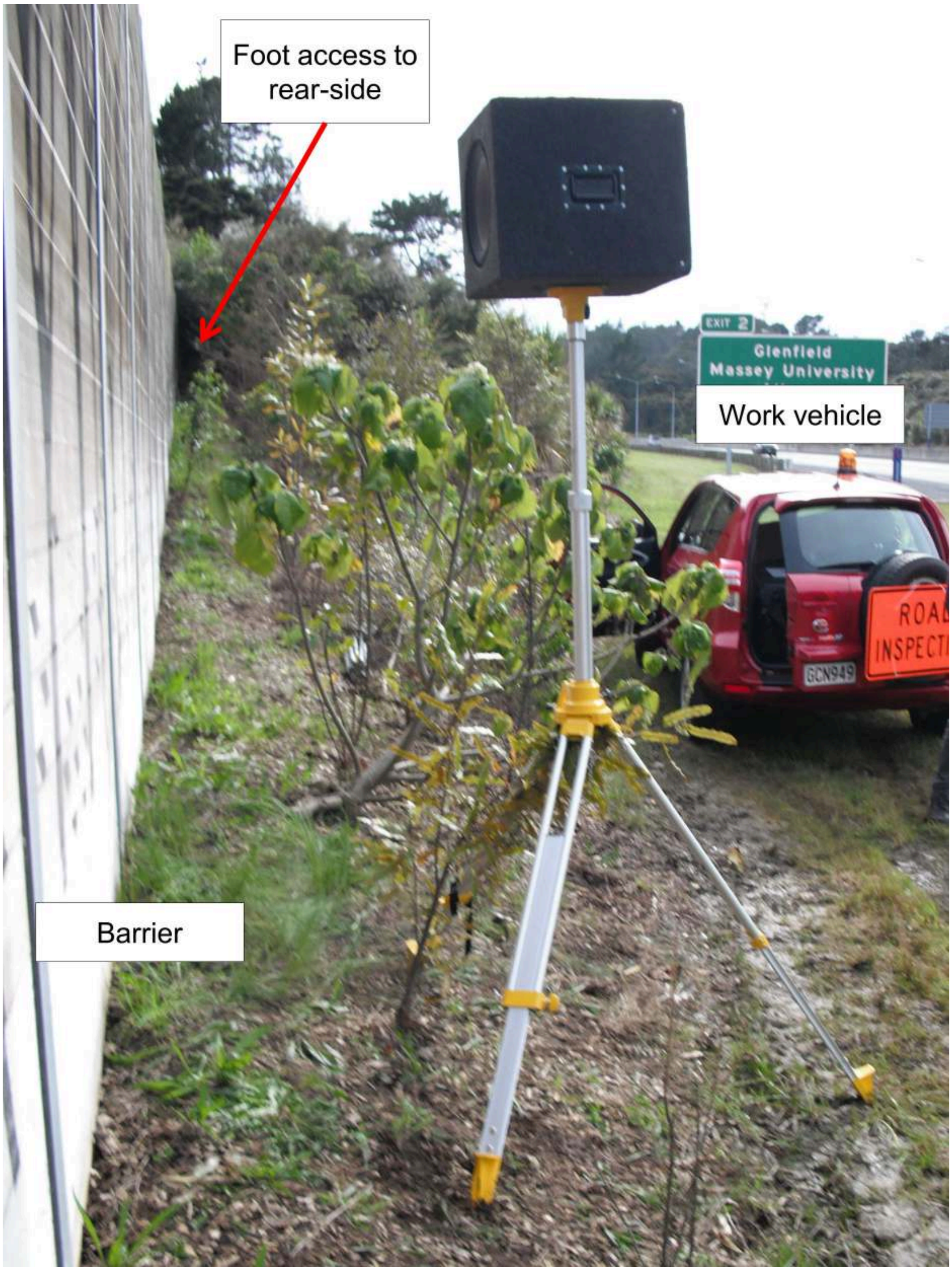

Figure 3 Road inspection site layout, Greenhithe

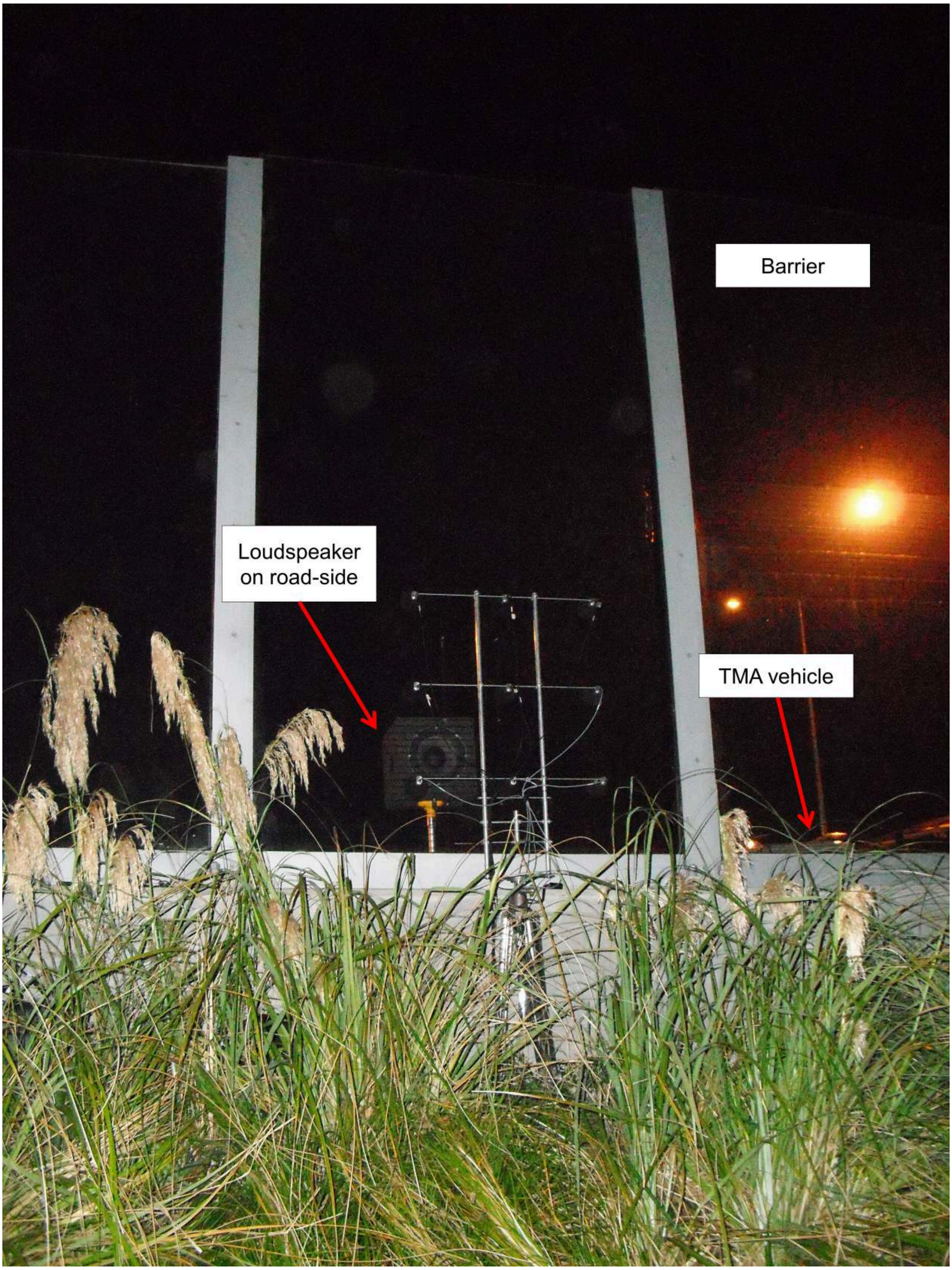

Figure 4 Semi-static closure site layout, St Marys Bay

4 Traffic Noise Barrier Performance

4.1 Calculation Parameters

The choice of which components of the transmitted signal to include in the analyses will affect the calculated values of the airborne sound insulation. In some cases sound leaking through defects in the barrier significantly influenced the results. Therefore the choice of which transmitted components to include is described in this section. Comments are also made on the accuracy of the test method when measuring the two concrete traffic noise barriers.

The test reports for each of the eight traffic noise barriers are included in Appendices B to I. These generally contain the results from a typical panel and post measurement. At most sites more measurements were conducted than those included in the test reports for the purpose of a more in depth analysis of the barrier performance beyond the requirements of EN1793-6. The test signal used for all measurements was a maximum length sequence (MLS) of order 16, repeated 16 times. A sampling frequency of 65,536 Hz provided a total test signal length of 16 seconds.

4.1.1 Acrylic Barrier at St Marys Bay

Gaps between the acrylic sheets and the concrete crash barrier at the St Marys Bay site allow a considerable amount of sound through to the rear-side of the barrier (Figure 5).

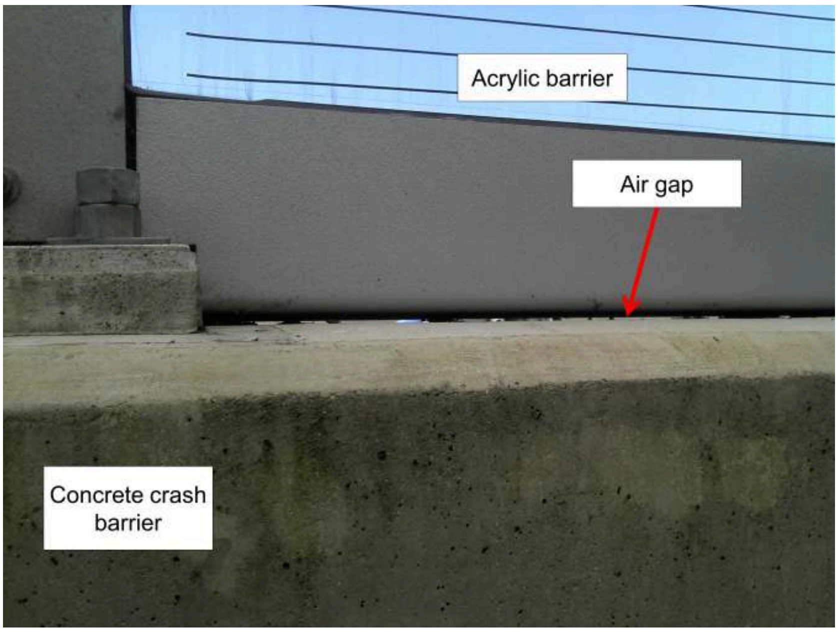

Figure 5 Air gap between the concrete crash barrier and acrylic panel at St Marys Bay

The loudspeaker/centre microphone height was limited due to the presence of the concrete crash barrier; the leakage components have been excluded from the calculation of the airborne sound insulation in the test report as they would not be present if the test was performed at half the barrier height as intended. The effect of including the leakage components in the time window is shown in Figure 6. Refer to the test report in Appendix B for details of the acrylic barrier at St Marys Bay.

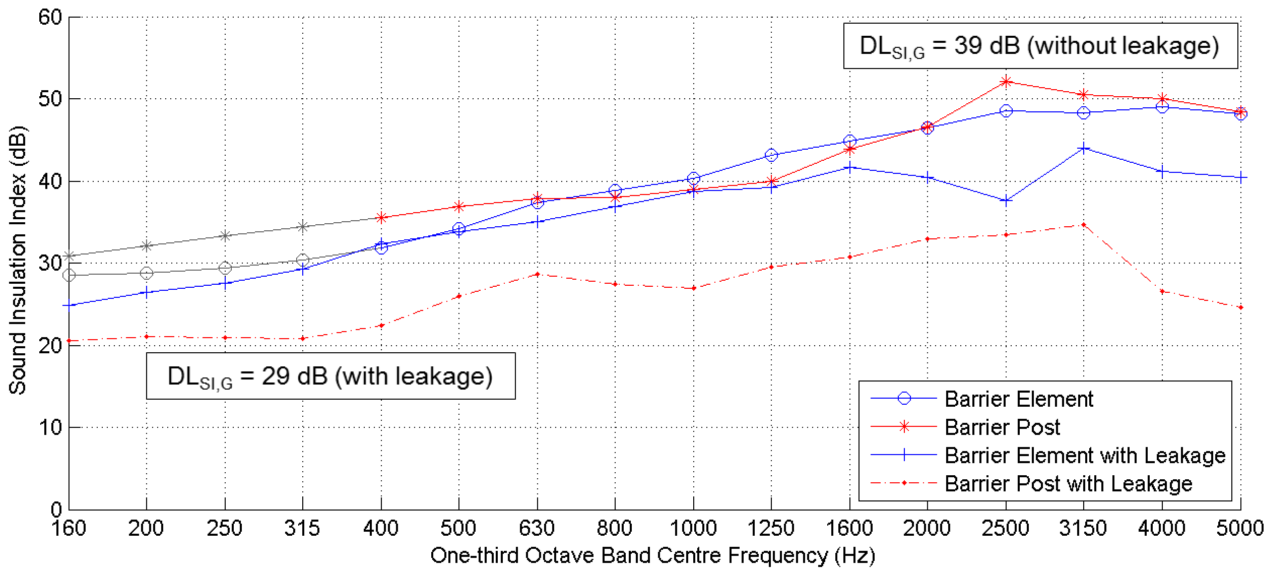

Figure 6 Airborne sound insulation of the traffic noise barrier at St Marys Bay with and without the leakage components. The global single number ratings are included. The grey lines represent values below the low frequency limit of the measurement.

Excluding the leakage components gives the effective airborne sound insulation of the panels and posts, which would be achieved in practice if the air gaps were adequately sealed.

4.1.2 Engineered Timber Barriers at Greenhithe and Maioro Street

Some leakage was observed around the panel edges for both the Greenhithe and Maioro Street engineered timber barriers. The shorter barrier at Maioro Street required a time window of 4.5ms in order to eliminate the diffraction component over the top of the barrier. This short time window also removed the leakage components in the element measurement at the Maioro Street site. A window length of 4.5ms was chosen at the Greenhithe site so that a fair comparison could be made between the two engineered timber barriers. The effect of including the leakage components at the Greenhithe barrier elements is shown in Figure 7. Refer to the test report in Appendix C for details of the engineered timber barrier at Greenhithe and Appendix D for details of the engineered timber barrier at Maioro Street.

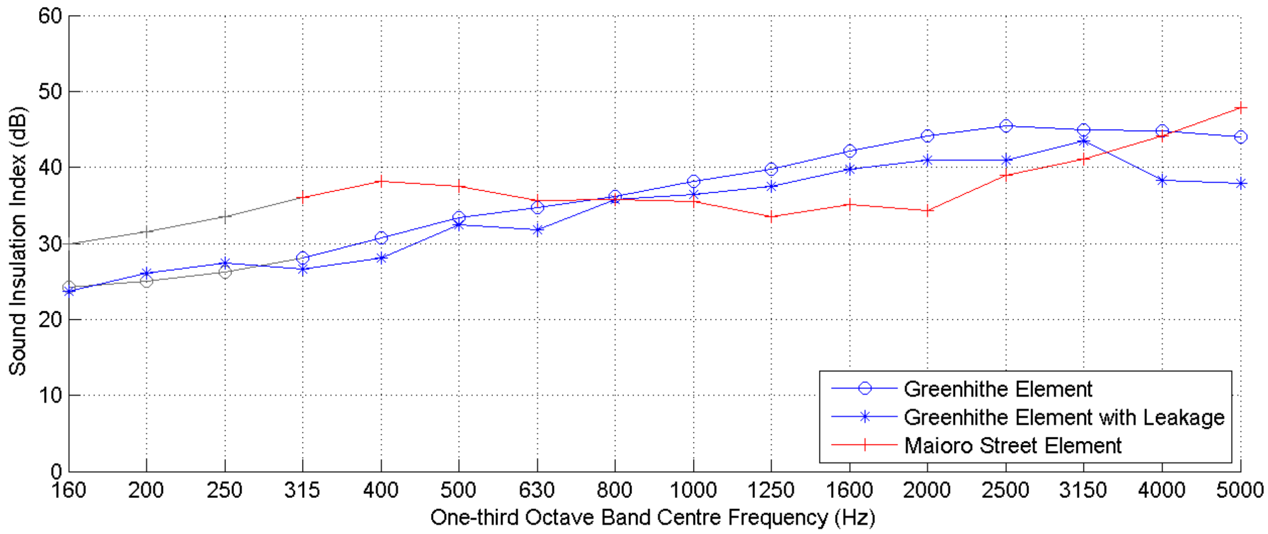

Figure 7 Airborne sound insulation of the engineered timber barrier elements at Greenhithe and Maioro Street, showing the effect of using a larger time window at the Greenhithe site. The grey lines represent values below the low frequency limit of the measurement.

4.1.3 Concrete Barriers at Green Lane and Maioro Street

Both concrete traffic noise barriers perform well, with high airborne sound insulation values. Figure 8 shows the airborne sound insulation of the two concrete barriers. Refer to the test report in Appendix E for details of the concrete barrier at Maioro Street and Appendix G for details of the concrete barrier at Green Lane.

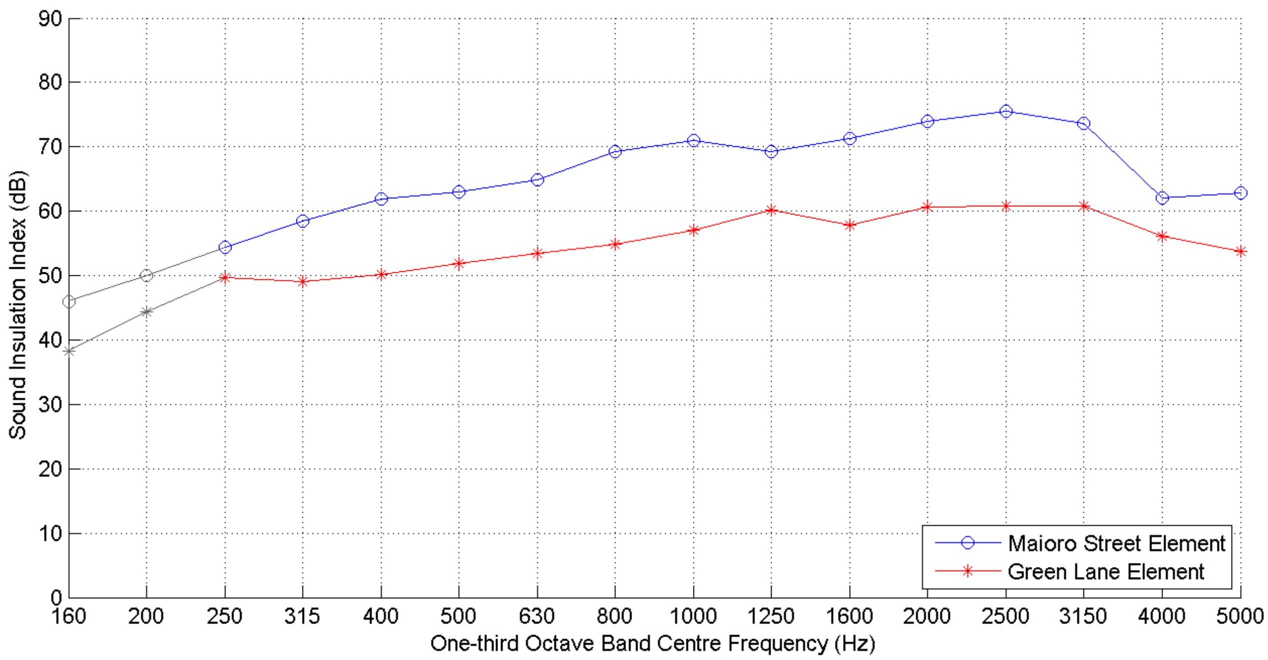

Figure 8 Airborne sound insulation of the concrete barriers at Green Lane and Maioro Street. The grey lines represent values below the low frequency limit of the measurement.

There will be an upper limit on the sound insulation values that can be detected by the equipment. This is likely being reached when measuring the concrete barriers where the level of the transmitted signal is comparable to the background noise level. It is possible that the difference seen in Figure 8 is due mainly to the variation in background noise level between the sites.

4.1.4 Plywood and Timber Barriers

The airborne sound insulation values of the two plywood barriers (Hobsonville and Northern Busway) and the timber barrier (Kingsland Cycleway) are shown in Figure 9. The poor performance of the Kingsland Cycleway barrier is due to air gaps between the overlapped timber planks leading to a large amount of sound leakage.

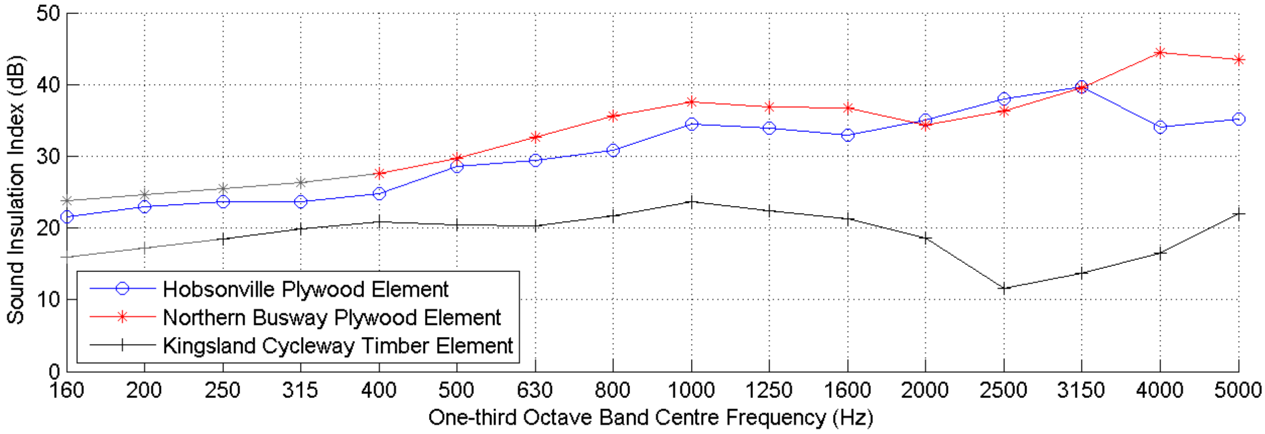

Figure 9 Airborne sound insulation of the plywood and timber traffic noise barrier elements at Hobsonville, Northern Busway and Kingsland Cycleway. The grey lines represent values below the low frequency limit of the measurement.

Refer to the test report in Appendix F for details of the plywood barrier at Hobsonvile, Appendix H for details of the timber barrier at Kingsland Cycleway and Appendix I for details of the plywood barrier at the Northern Busway.

4.2 Comparison of the Different Barrier Types

The global airborne sound insulation values are summarised in Table 4 and plotted in Figure 10.

Table 4 Single number rating for the global airborne sound insulation, $DL_{SI,G}$

Name	*Material*	*Global Single Number Rating with Low Frequency Limits*	*Category*
Maioro Street	concrete	65 dB (250Hz)	D4
Green Lane	concrete	55 dB (250Hz)	D4
St Marys Bay	acrylic	39 dB (400Hz)	D4
Maioro Street	engineered timber	35 dB (315Hz)	D3
Northern Busway	plywood	34 dB (400Hz)	D3
Greenhithe	engineered timber	33 dB (315Hz)	D3
Hobsonville	plywood	29 dB (160Hz)	D3
Kingsland Cycleway	timber	19 dB (250Hz)	D2

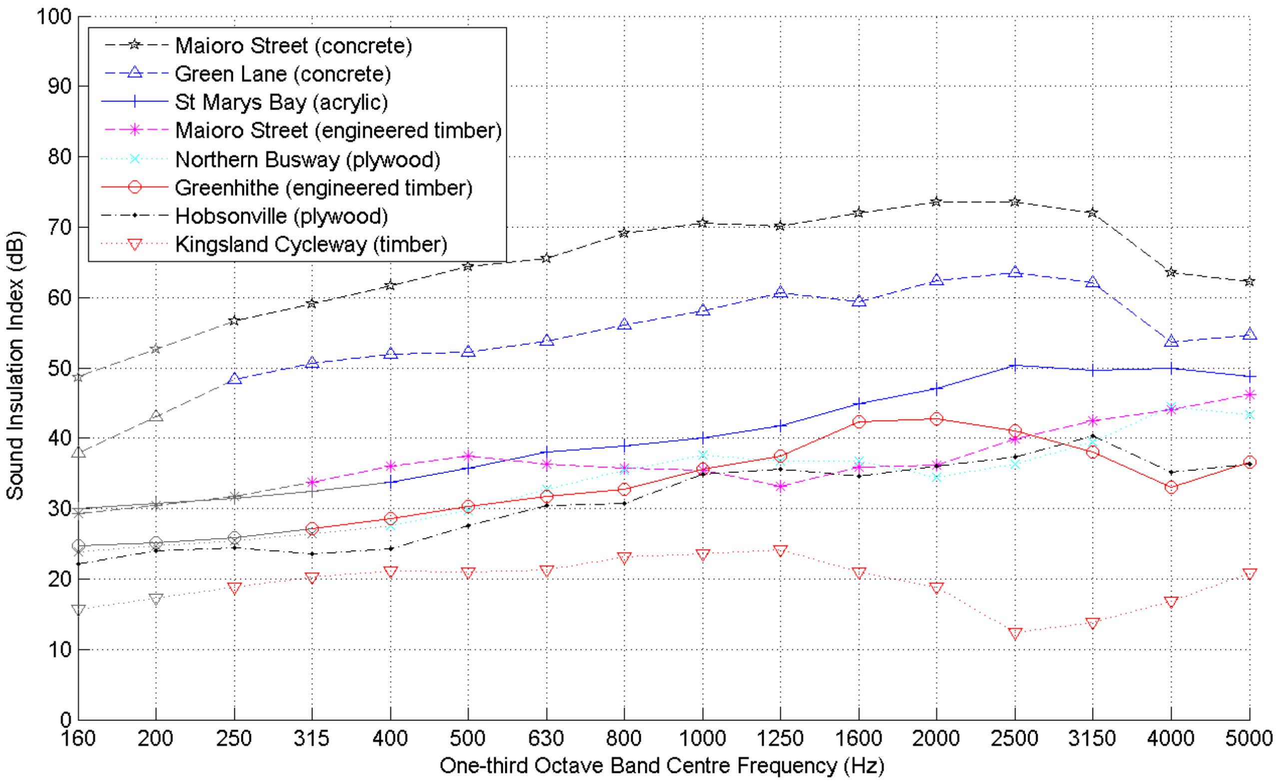

Figure 10 Global airborne sound insulation of the Auckland traffic noise barriers. The grey lines represent values below the low frequency limit of the measurements.

The concrete barriers out perform all of the other traffic noise barriers across the entire frequency range, which is expected due to their mass and lack of significant air gaps. The acrylic barrier at St Marys Bay is the next best performing with a single number rating of 39 dB, however if the gap between the concrete crash barrier and acrylic panel is included then the single number rating falls to 29dB. It is clear that the presence of such gaps can significantly degrade the barrier performance.

The plywood and engineered timber barriers have single number ratings ranging from 29 dB to 35 dB. The slatted timber barrier at Kingsland Cycleway is the worst performing with a single number rating of 19 dB. The use of timber frequently increases the number of air gaps, consequently reducing the airborne sound insulation. These results are in line with previous studies which showed that single number ratings for single leaf timber barriers ranged from 20 dB to 26 dB (Watts and Morgan, 2007). Garai and Guidorzi (2000) demonstrated the much higher airborne sound insulation values of concrete barriers.

4.3 Ageing of the Engineered Timber Barrier

The engineered timber barriers at Greenhithe and Maioro Street are of the same construction, with the Greenhithe traffic noise barrier being approximately four years older than the barrier at Maioro Street. The single number ratings for the global airborne sound insulation are 33 dB at the Greenhithe site and 35 dB at the Maioro Street site (Table 4). The airborne sound insulation values for each site are plotted in Figure 11.

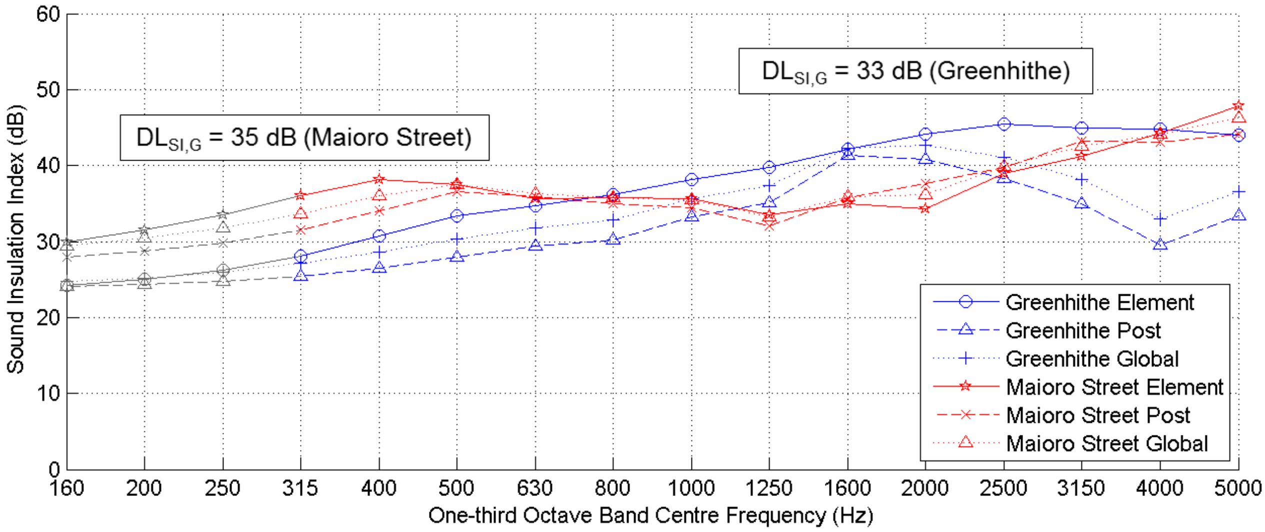

Figure 11 Comparison between the airborne sound insulation values for the Greenhithe and Maioro Street engineered timber barriers. The global single number ratings are included. The grey lines represent values below the low frequency limit of the measurement.

The newer barrier at Maioro Street is more consistent, with both the element and post measurements giving similar values, while the post measurement at the Greenhithe site shows that some leakage is occurring. During testing it was noticed that some of the Greenhithe barrier panels were loose, rattling in their I-section posts.

There is some variation between the airborne sound insulation values of the elements at each site, with the Greenhithe barrier element performing better above 800Hz. The cause of this variation in airborne sound insulation is unclear.

5 Conclusions

5.1 Barrier Acoustic Performance

The concrete traffic noise barriers at Green Lane and Maioro Street are the best performing barriers, both having a D4 classification for their airborne sound insulation. The acrylic barrier at St Marys Bays also has a D4 classification, however when the air gap between the concrete crash barrier and the acrylic panel is included the performance drops to a D3 classification. This highlights the importance of minimising air gaps during the design and construction of a barrier.

The engineered timber and plywood barriers have a D3 classification, while the slatted timber barrier at Kingsland Cycleway has a D2 classification. This reduced performance is due to the presence of air gaps between the overlapping timber planks which have warped with age. The values of airborne sound insulation of the Auckland traffic noise barriers are in line with previous studies.

5.2 Time Requirements

The Auckland traffic noise barrier measurements were conducted over three daytime testing sessions and one night-time testing session. The number of measurement positions at each site was limited in order to have enough time to visit as many sites as possible and gain experience in testing at each of these sites. While the data set collected allows reliable comparisons to be made between the different barriers, in general measurements should be conducted at a greater number of positions along a barrier in order to gain a complete understanding of the airborne sound insulation. It is advised that in future a full day is devoted to testing each barrier, therefore allowing any variations along the barrier length, leaks and defects to be investigated.

Testing work at semi-static closure sites was limited to 30 minutes, allowing a maximum of three measurements to be performed. Consideration should be given to scheduling future work at these sites to coincide with road maintenance activities were a lane closure is required. This will allow for more extensive testing of these barriers.

5.3 Microphone and Loudspeaker Positions

According to EN1793-6 the microphone must be positioned 0.25 metres away from the barrier, and the loudspeaker 1 metre away from the barrier. Both structural and acoustical elements are included in the definition of the barrier. This requirement was not followed during the Auckland testing work where only the barrier panels were considered. In some cases the microphones would be positioned up to 0.75 metres away from the barrier (Hobsonville site) if the positioning requirement of the standard were exactly followed. Further investigation into this aspect of EN1793-6 will be conducted as part of the ongoing barrier research at the University of Canterbury.

5.4 Loudspeaker/Centre Microphone Height

The loudspeaker/centre microphone height is specified in EN1793-6 to be half of the barrier height. This was not achieved at the St Marys Bay site where the presence of a concrete crash barrier prevented the loudspeaker from being raised to the required height. This resulted in a low frequency limit of 400Hz where a limit of 160Hz should have been attainable. Different loudspeaker mounting equipment is needed when the loudspeaker must be partially mounting on a crash barrier such as that at the St Marys Bay site.

The loudspeaker/centre microphone height at the Green Lane site was based on the barrier height on the rear-side, which resulted in the loudspeaker being 0.5 metres above the concrete crash barrier due to the higher ground level on the road-side. This did not meet the loudspeaker height requirement of EN1793-6 where the loudspeaker height should be half of the barrier height. Reference should be made to the barrier design drawings when planning future measurements, to ensure that the correct loudspeaker height is determined before arriving at the test site.

5.5 Maximum Measurable Airborne Sound Insulation

The airborne sound insulation values calculated for the two concrete traffic noise barriers at Green Lane and Maioro Street are unlikely to fairly reflect the barrier performance. EN1793-6 calls for an effective signal-to-noise ratio of at least 10 dB, which could not be reached without producing excessively high sound pressure levels. There was a concern regarding resident annoyance and the accuracy of the test method when exciting the barrier with such high sound pressure levels. Further work is being conduced into the accuracy of the test method when testing these high performance barriers as part of the ongoing barrier research at the University of Canterbury.

5.6 Test Standard

EN1793-6:2011 is a draft standard and the issues raised from this work will help to inform further developments of the European standard, particularly with regard to:

- background noise immunity of the test signal
- microphone off-set distance and its effect on the measured values
- choice of loudspeaker and its effect on the measured values
- improvements to measurement procedures to reduce risks and delays to the operators and road users
- sampling of panels and posts

6 References

CEN (2003) CEN/TS 1739-4:2003 Road traffic noise reducing devices - Test method for determining the acoustic performance - Part 4: Intrinsic characteristics - In situ values of sound diffraction.

CEN/TC226/WG6/TG1 N 430 (2011) EN1793-6:2011 Road traffic noise reducing devices - Test method for determining the acoustic performance - Part 6: Intrinsic characteristics - In situ values of airborne sound insulation under direct sound field conditions.

Garai, M. and Guidorzi, P. (2000) European methodology for testing the airborne sound insulation characteristics of noise barriers in situ: experimental verification and comparison with laboratory data. *J. Acoust. Soc. Am. 108(3):1054-1067*.

Watts, G. and Morgan, P. (2007) Measurement of airborne sound insulation of timber noise barriers: comparison of in situ method CEN/TS 1793-5 with laboratory method EN 1793-2. *Applied Acoustics 68:421-436*.

Appendix A

Summary of EN1793-6:2011

A.1 Introduction

EN1793-6:2011, *Road traffic noise reducing devices - Test method for determining the acoustic performance - Part 6: Intrinsic characteristics - In situ values of airborne sound insulation under direct sound field conditions* is a draft European standard developed to measure the effectiveness of a barrier at reducing the transmitted sound (Figure A.1).

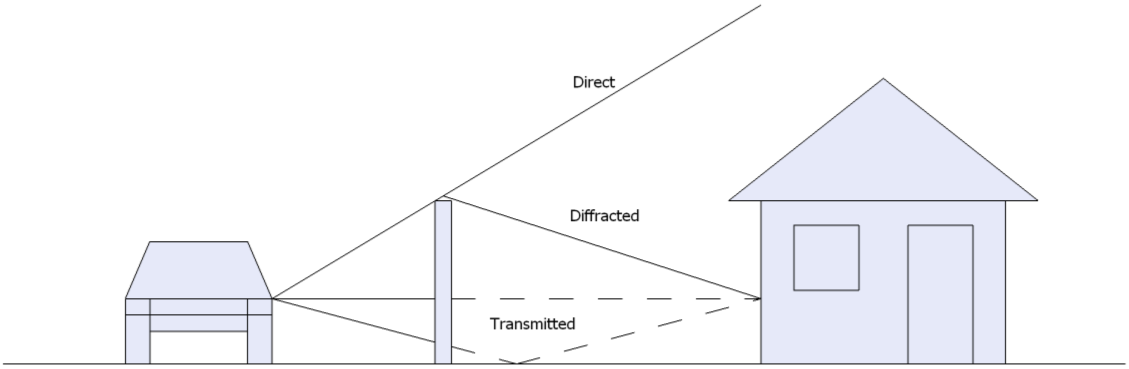

Figure A.1 Principal sound paths, EN1793-6 is concerned with the transmitted sound

A.2 Equipment and Test Setup

The measurement equipment consisted of:

- array of nine microphones, mounting frame and tripod
- loudspeaker (12 inch, 600W, sealed loudspeaker) and tripod
- amplifier and power supply for the loudspeaker
- Bruel & Kjaer PULSE C-frame (data acquisition unit)
- test signal (MLS or swept sine)
- laptop computer

A block diagram of the measurement equipment is shown in Figure A.2.

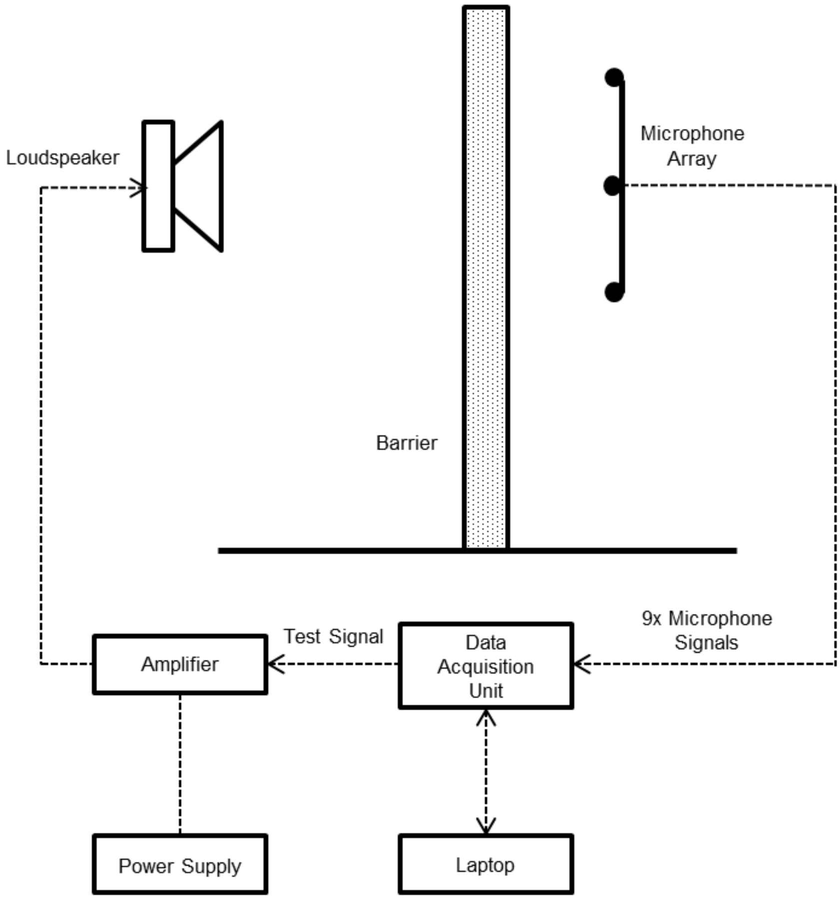

Figure A.2 Diagram of the measurement equipment

The measurement equipment is setup at a test site as follows:

- the loudspeaker is positioned on the road-side of the barrier, 1 metre away from the most protruding part of the barrier structure
- the microphone array is positioned on the rear-side of the barrier, 0.25 metres away from the most protruding part of the barrier structure
- the loudspeaker/centre microphone height is half of the barrier height
- the loudspeaker/centre microphone axis is located horizontally in the middle of a panel for a panel measurement and in line with a post for a post measurement

Figure A.3 shows the measurement equipment layout at a test site with a 4 metre high barrier.

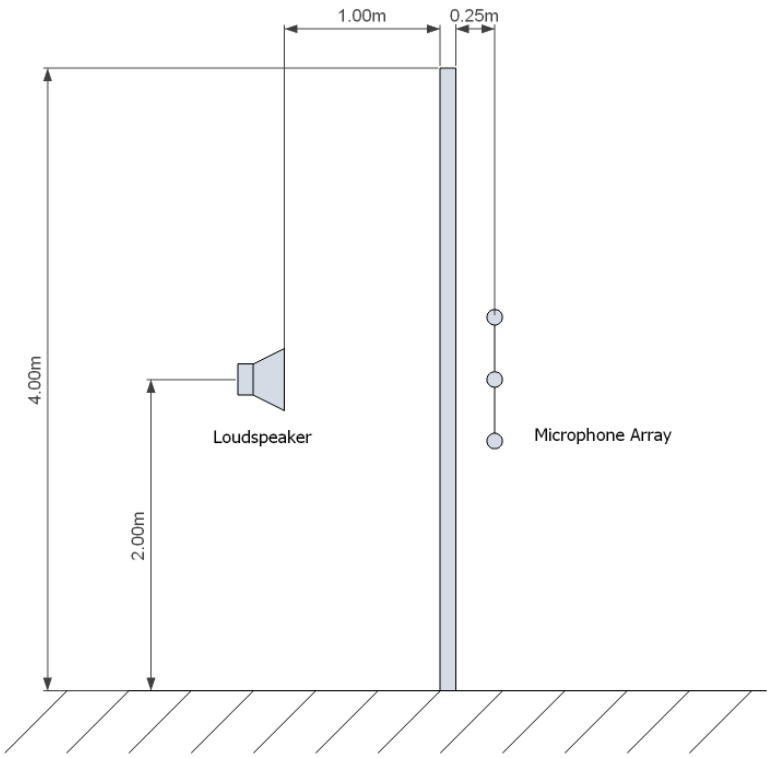

Figure A.3 Layout of the measurement equipment at a 4 metre high barrier

A.3 Calculation of the Airborne Sound Insulation Index

The airborne sound insulation index is calculated from the impulse response of the barrier, measured at the nine microphone positions. The impulse response is windowed using the Adrienne temporal window so that the diffraction sound path and any parasitic reflections are excluded for the impulse response, see Figure A.4.

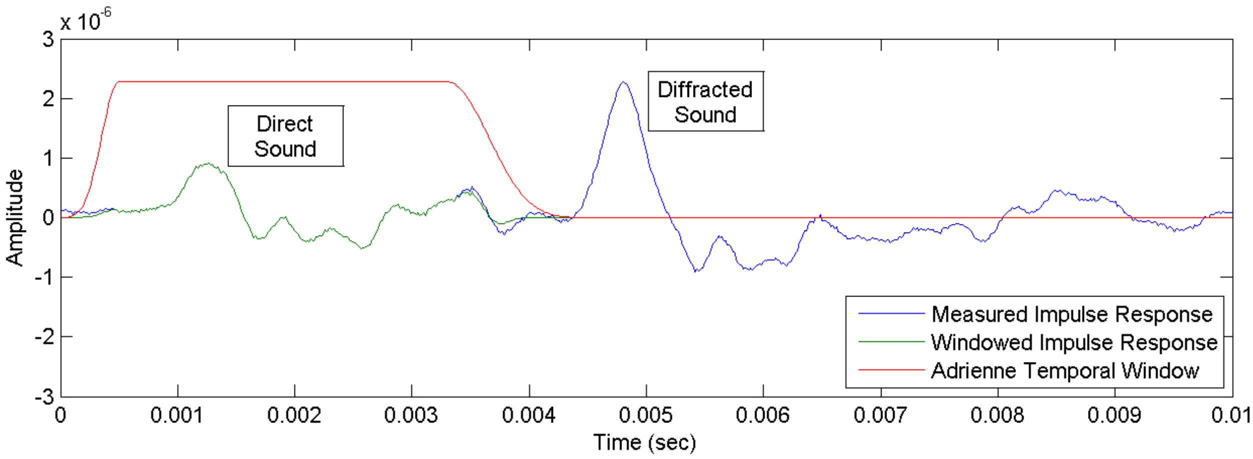

Figure A.4 Impulse response showing the removal of the diffracted sound

The frequency response of the barrier and free-field measurements are then calculated from the respective windowed impulse responses, and the sound insulation index calculated using the equation in Section 4.2 of EN1793-6:2011.

A.3.1 Single Number Rating

The single number rating DL_{SI} is calculated by weighting the the sound insulation index according to the normalised traffic noise spectrum defined in EN1793-3 and using the equations in Section 4.8 of EN1793-6:2011. Figure A.5 shows the normalised traffic noise spectrum with a representative sound insulation index curve.

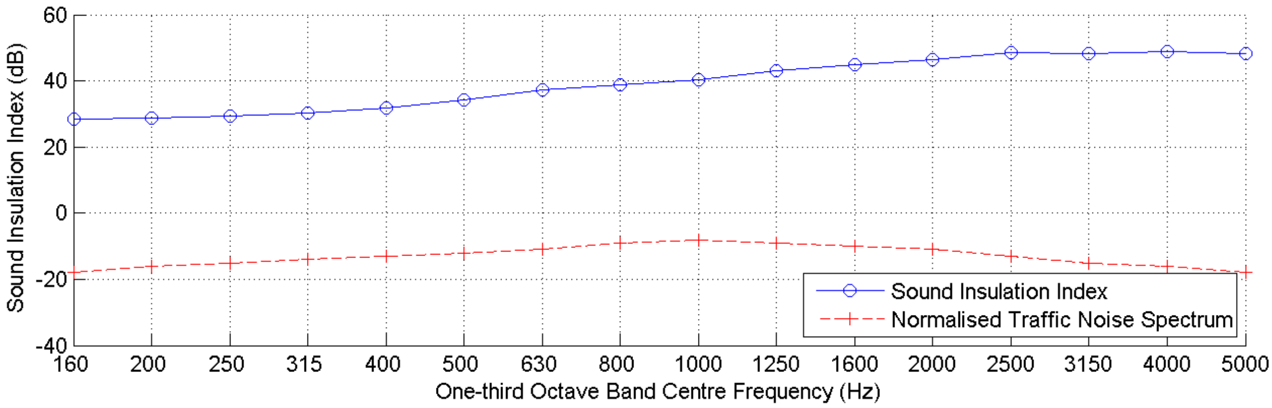

Figure A.5 Typical sound insulation index curve for a barrier element with the normalised traffic noise spectrum

The single number ratings can be used to categorise the airborne sound insulation performance using Table A.1.

Table A.1 Categories of airborne sound insulation

Category	*Single Number Rating, DL_{SI} (dB)*
D0	Not determined
D1	< 16
D2	16 to 27
D3	28 to 36
D4	> 36

Appendix B

Airborne Sound Insulation of the 3.6m Acrylic Barrier at St Marys Bay

B.1 Introduction

The tests described in this report were conducted on 26 October 2012. The tests were performed at the request of the NZ Transport Agency (NZTA) to determine the airborne sound insulation of the acrylic traffic noise barrier at St Marys Bay.

The tests were performed in accordance with the draft European standard EN1793-6:2011 *Road traffic noise reducing devices - Test method for determining the acoustic performance - Part 6: Intrinsic characteristics - In situ values of airborne sound insulation under direct sound field conditions*.

B.2 Test Summary

Name and address of testing organisation:
Acoustics Research Group
University of Canterbury
Christchurch 8041
New Zealand

Test Date:
26 October 2012
Test Location:
St Marys Bay

Test Setup:
see description and photographic presentation in Section B.3

Test Object:

Manufacturer:	Plastral
Type:	acrylic
Dimensions:	3.6m high, 2m wide, 15mm thick
Date of installation:	2011
Physical condition during test (visual inspection):	gaps between panels and crash barrier
Composition:	see description and photographic presentation in Section B.4

Meteorological conditions prevailing during the test:

Wind speed:	0 m/s
Air temperature:	12.6 °C
Air pressure:	100.90 kPa
Relative Humidity:	81 %

Test arrangement:
see description and photographic presentation in Section B.3

Equipment used for measurement and analysis:

Sound source

Description:	single driver (12 inch diameter, 600W) sealed loudspeaker, enclosure dimensions: 400mm x 400mm x 450mm

Microphones

Manufacturer:	Bruel & Kjaer
Type:	Type 4189 (1/2" pre-polarised, free-field) Type 2669-C preamplifier (microphones 1-5) Type 2669-L preamplifier (microphones 6-9)
Serial numbers:	2573559 (microphone 1) 2573560 (microphone 2) 2573563 (microphone 3) 2573562 (microphone 4) 2573561 (microphone 5) 2626749 (microphone 6) 2593736 (microphone 7) 2674393 (microphone 8) 2674394 (microphone 9)

Analyser

Manufacturer:	Bruel & Kjaer
Type:	Type 7539 (5 channels)
Serial number:	2472233

Filtering and sampling

Anti-aliasing filter type:	3rd order Butterworth
Sample rate:	65,536 Hz

Adrienne temporal window

Length:	3.5 ms (barrier element) 3.5 ms (barrier post)

Test frequency range

Low frequency limit:	400 Hz (barrier element), 400 Hz (barrier post)
Smallest dimension:	3.6m (barrier height)

Test results

see tables and graphs in Section B.5

Single-number ratings

The single-number ratings for the airborne sound insulation amount to:

$DL_{SI,E}$ = 39 dB (element)	Category: D4
$DL_{SI,P}$ = 40 dB (post)	Category: D4
$DL_{SI,G}$ = 39 dB (global)	Category: D4

B.3 Test Setup

The barrier under test is a single-leaf, reflective acrylic traffic noise barrier. The barrier height varies along its length, ranging between 2m and 5m. The element under test was 2m wide x 3.6m high, supported by T-section posts at 2m centres. The section of barrier under test is situated on the western side of SH1. Figure B.1 shows the traffic noise barrier viewed from the road-side.

The crosses in Figure B.1 show the approximate positions of the loudspeaker/centre microphone axis. The measurement points are on the rear-side of the barrier, on a vertical measurement grid of 3 x 3 points with equal horizontal and vertical distances of 0.40m. This measurement grid was located horizontally in the middle of an element (element measurement, position 1) and in line with a post (post measurement, position 2). The element measurement at postion 3 has not been included in this report.

The loudspeaker/centre microphone height was 1.25m above the concrete crash barrier for the element measurement at position 1, and 0.8m above the concrete crash barrier for the post measurement at position 2. The barrier thickness at the height of measurement is 15mm.

The Adrienne temporal window length has been chosen to exclude any parasitic reflections that may otherwise affect the measurement results, including the leakage component due to gaps between the acrylic panels and concrete crash barrier.

The loudspeaker and microphone array are shown in Figure B.1 and B.2, respectively.

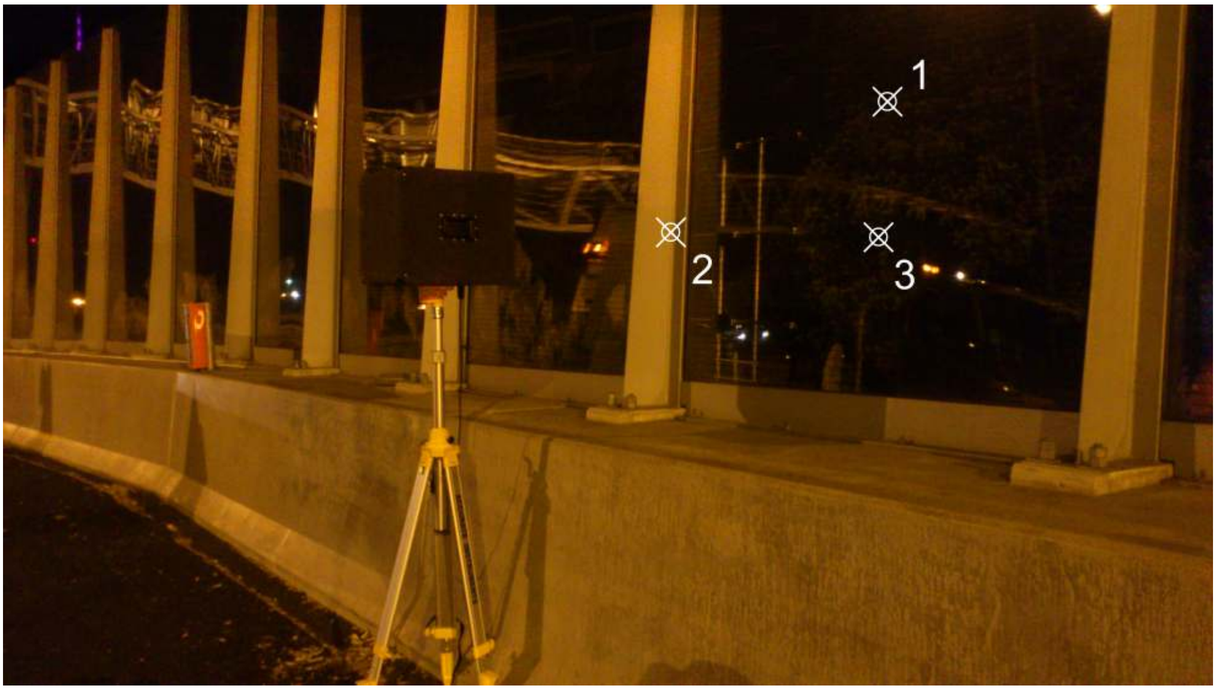

Figure B.1 Test arrangement showing the loudspeaker when measuring across a post (position 2), the crosses mark the measurement positions

Figure B.2 Test arrangement showing the microphone array when measuring across an element (position 3)

B.4 Test Object

Figure B.3 shows the composition of the acrylic traffic noise barrier. Each element of the barrier is constructed from two acrylic panels, the joint in this case is 1.65m above the concrete crash barrier. The acrylic panels are clamped in the T-section posts with a length of flat section as shown in Figure B.3.

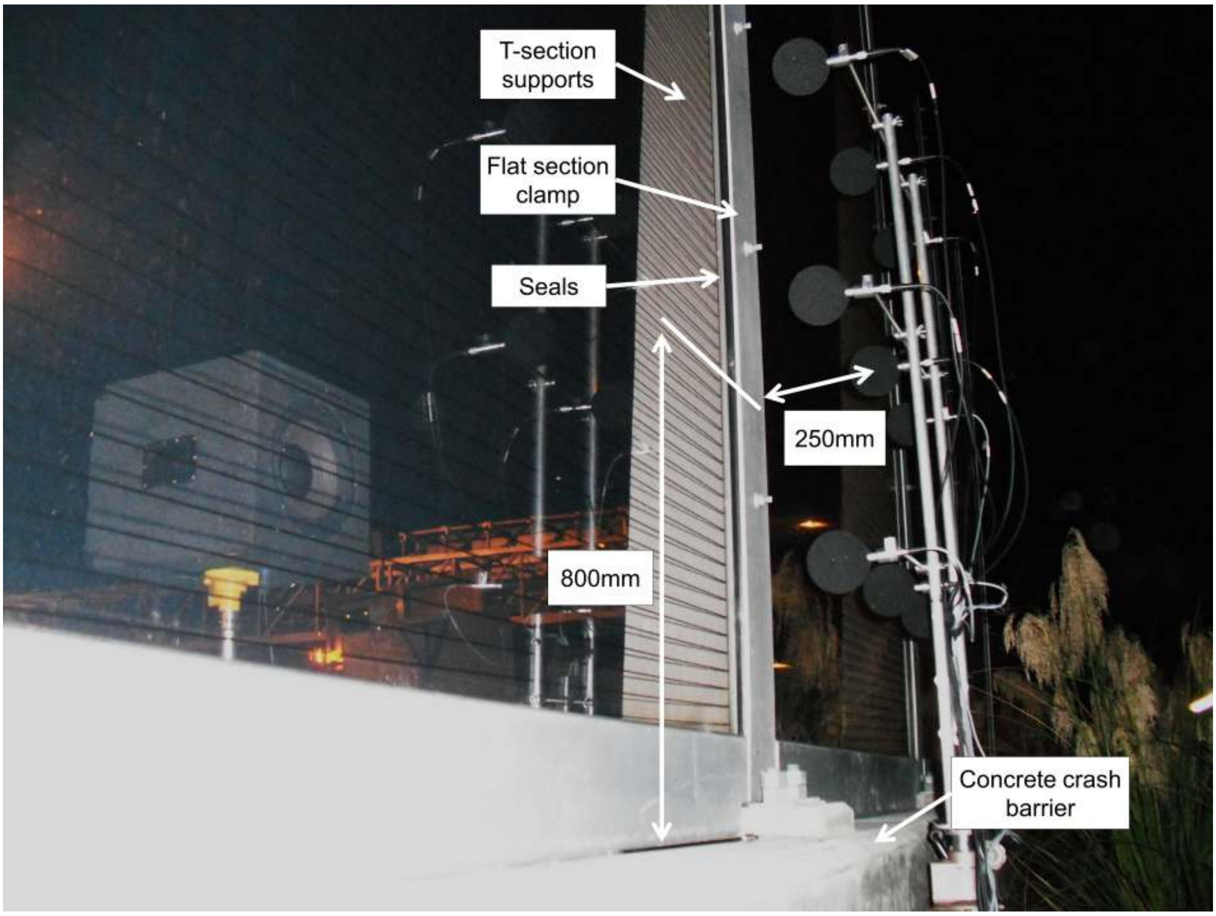

Figure B.3 Composition of the acrylic traffic noise barrier, test setup during a post measurement (position 2)

B.5 Results

B.5.1 Results for Barrier Element

Table B.1 Airborne sound insulation values at nine microphone positions and logarithmic average for the element measurement, highlighted values are below the low frequency limit

Microphone	*One-third Octave Band Centre Frequency (Hz)*															
Positions	160	200	250	315	400	500	630	800	1k	1.25k	1.6k	2k	2.5k	3.15k	4k	5k
SI_1	29.6	29.8	30.3	31.0	32.2	34.3	37.4	39.3	40.4	43.2	45.8	47.5	49.3	48.9	51.0	49.2
SI_2	28.7	29.1	29.8	30.8	32.5	35.2	38.5	39.0	40.9	43.7	46.4	48.2	51.2	52.2	51.4	47.8
SI_3	27.7	28.1	28.9	30.1	31.9	34.9	38.6	39.2	41.3	43.9	44.8	45.8	49.7	46.4	50.1	46.0
SI_4	30.2	30.4	30.9	31.6	32.9	35.0	38.1	39.6	40.7	43.7	45.8	47.9	49.7	51.0	50.0	51.1
SI_5	28.4	28.8	29.6	30.7	32.4	35.0	38.4	39.8	41.4	44.0	45.8	47.7	49.6	51.0	53.4	55.0
SI_6	29.0	29.4	30.1	31.1	32.7	35.1	38.2	39.4	41.3	44.1	45.4	46.5	48.2	49.6	51.0	48.8
SI_7	29.3	29.5	30.0	30.8	32.0	34.1	37.2	39.4	40.4	43.2	45.0	46.9	49.0	48.5	47.5	48.7
SI_8	29.2	29.6	30.1	31.0	32.3	34.5	37.6	39.7	40.6	43.4	45.1	47.0	48.2	49.5	49.7	51.4
SI_9	29.0	29.4	29.9	30.8	32.2	34.4	37.3	39.0	40.5	43.5	44.4	45.7	47.5	46.0	46.1	46.2
Average	28.5	28.8	29.4	30.4	31.8	34.2	37.4	38.9	40.3	43.1	44.9	46.4	48.5	48.3	49.0	48.1

Single number rating of the airborne sound insulation across an element, $DL_{SI,E}$ = 39 dB, with a low frequency limit of 400 Hz.

B.5.2 Results for Barrier Post

Table B.2 Airborne sound insulation values at nine microphone positions and logarithmic average for the post measurement, highlighted values are below the low frequency limit

Microphone	*One-third Octave Band Centre Frequency (Hz)*															
Positions	160	200	250	315	400	500	630	800	1k	1.25k	1.6k	2k	2.5k	3.15k	4k	5k
SI_1	30.1	30.4	30.9	31.6	32.8	34.4	36.1	36.2	36.7	39.0	43.1	47.9	54.6	57.0	47.1	44.3
SI_2	33.7	34.2	34.9	35.8	37.3	39.8	43.8	47.2	48.2	50.4	52.3	57.8	57.7	64.8	62.7	52.4
SI_3	28.5	30.4	32.3	33.8	35.3	37.5	39.9	38.3	37.9	39.7	43.2	43.8	47.3	47.2	47.2	43.9
SI_4	30.7	31.4	32.1	32.8	33.6	34.5	35.3	36.2	38.4	39.3	43.9	48.3	53.6	49.2	46.9	49.9
SI_5	34.0	35.4	36.7	38.0	39.4	41.0	42.6	44.6	47.2	47.5	52.4	53.9	57.8	57.5	59.6	59.1
SI_6	33.3	33.9	34.5	35.1	35.8	36.7	37.5	38.3	40.5	40.7	42.8	44.6	51.5	50.6	60.4	49.5
SI_7	30.4	32.3	34.1	35.7	36.8	37.1	36.5	35.6	36.2	37.1	45.9	46.1	56.3	47.8	50.6	53.3
SI_8	33.1	35.3	37.6	39.6	41.3	42.8	44.3	45.3	45.4	44.8	48.9	55.0	53.8	54.5	53.9	60.9
SI_9	31.6	33.5	35.4	37.1	38.3	39.1	39.3	39.0	40.0	38.9	40.8	44.5	51.9	51.3	52.2	53.8
Average	30.8	32.1	33.3	34.4	35.5	36.8	37.9	38.0	39.0	39.9	43.9	46.6	52.0	50.5	50.0	48.4

Single number rating of the airborne sound insulation across a post, $DL_{SI,P}$ = 40 dB, with a low frequency limit of 400 Hz.

B.5.3 Results for Barrier Global

Table B.3 Airborne sound insulation values at nine microphone positions and logarithmic average for the global measurement, highlighted values are below the low frequency limit

Microphone Positions	160	200	250	315	400	500	630	800	1k	1.25k	1.6k	2k	2.5k	3.15k	4k	5k
SI_1	29.8	30.1	30.6	31.3	32.5	34.4	36.7	37.5	38.1	40.6	44.2	47.7	51.2	51.2	48.6	46.1
SI_2	30.5	30.9	31.6	32.7	34.3	36.9	40.4	41.4	43.2	45.9	48.4	50.8	53.3	55.0	54.1	49.6
SI_3	28.1	29.1	30.3	31.5	33.3	36.0	39.2	38.7	39.3	41.3	43.9	44.7	48.3	46.8	48.4	44.8
SI_4	30.5	30.9	31.5	32.2	33.2	34.8	36.5	37.5	39.4	41.0	44.7	48.1	51.2	50.0	48.2	50.5
SI_5	30.4	31.0	31.8	33.0	34.6	37.1	40.0	41.5	43.4	45.4	48.0	49.8	52.0	53.1	55.5	56.6
SI_6	30.7	31.1	31.8	32.7	34.0	35.8	37.8	38.8	40.8	42.1	43.9	45.4	49.6	50.1	53.5	49.1
SI_7	29.8	30.7	31.6	32.6	33.8	35.4	36.8	37.1	37.8	39.2	45.5	46.5	51.2	48.1	48.8	50.4
SI_8	30.7	31.6	32.4	33.4	34.8	36.9	39.8	41.7	42.4	44.0	46.6	49.4	50.1	51.3	51.3	53.9
SI_9	30.1	31.0	31.9	32.9	34.2	36.1	38.2	39.0	40.3	40.6	42.2	45.1	49.2	47.9	48.2	48.5
Average	30.0	30.7	31.4	32.4	33.8	35.8	38.1	38.9	40.1	41.7	44.9	47.0	50.4	49.7	50.0	48.8

(One-third Octave Band Centre Frequency (Hz))

Single number rating for the global airborne sound insulation, $DL_{SI,G}$ = 39 dB, with a low frequency limit of 400 Hz. If the air gap between the concrete crash barrier and acrylic panel is included in the measurement, the global single number rating falls to 29 dB with a low frequency limit of 160 Hz.

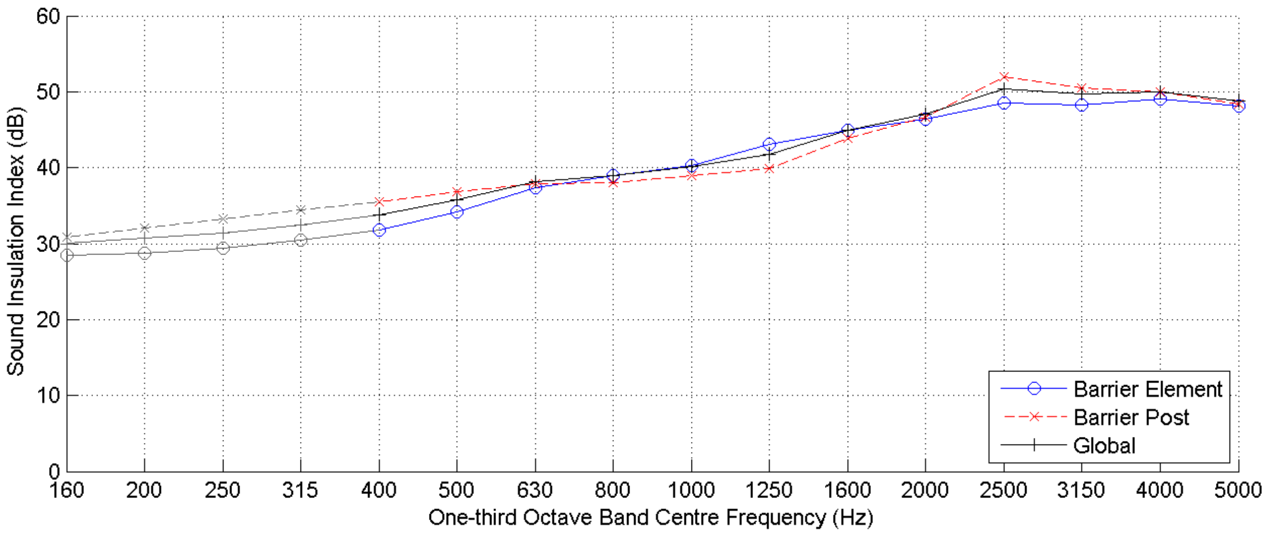

Figure B.4 Airborne sound insulation values, logarithmically averaged over nine microphone positions. The grey lines represent values below the low frequency limit of the measurement.

Appendix C

Airborne Sound Insulation of the 4.2m Engineered Timber Barrier at Greenhithe

C.1 Introduction

The tests described in this report were conducted on 25 October 2012. The tests were performed at the request of the NZ Transport Agency (NZTA) to determine the airborne sound insulation of the engineered timber traffic noise barrier at Greenhithe.

The tests were performed in accordance with the draft European standard EN1793-6:2011 *Road traffic noise reducing devices - Test method for determining the acoustic performance - Part 6: Intrinsic characteristics - In situ values of airborne sound insulation under direct sound field conditions*.

C.2 Test Summary

Name and address of testing organisation:
Acoustics Research Group
University of Canterbury
Christchurch 8041
New Zealand

Test Date:
25 October 2012
Test Location:
Greenhithe

Test Setup:
see description and photographic presentation in Section C.3

Test Object:

Manufacturer:	Nuibarrier
Type:	engineered timber
Dimensions:	4.2m high, 2.4m wide, 32mm thick
Date of installation:	2007
Physical condition during test (visual inspection):	some loose panels
Composition:	see description and photographic presentation in Section C.4

Meteorological conditions prevailing during the test:

Wind speed:	0 m/s
Air temperature:	24.9 °C
Air pressure:	100.63 kPa
Relative Humidity:	54.5 %

Test arrangement:
see description and photographic presentation in Section C.3

Equipment used for measurement and analysis:

Sound source

Description:	single driver (12 inch diameter, 600W) sealed loudspeaker, enclosure dimensions: 400mm x 400mm x 450mm

Microphones

Manufacturer:	Bruel & Kjaer
Type:	Type 4189 (1/2" pre-polarised, free-field) Type 2669-C preamplifier (microphones 1-5) Type 2669-L preamplifier (microphones 6-9)
Serial numbers:	2573559 (microphone 1) 2573560 (microphone 2) 2573563 (microphone 3) 2573562 (microphone 4) 2573561 (microphone 5) 2626749 (microphone 6) 2593736 (microphone 7) 2674393 (microphone 8) 2674394 (microphone 9)

Analyser

Manufacturer:	Bruel & Kjaer
Type:	Type 7539 (5 channels)
Serial number:	2472233

Filtering and sampling

Anti-aliasing filter type:	3rd order Butterworth
Sample rate:	65,536 Hz

Adrienne temporal window

Length:	4.5 ms (barrier element) 4.5 ms (barrier post)

Test frequency range

Low frequency limit:	315 Hz (barrier element), 315 Hz (barrier post)
Smallest dimension:	4.2m (barrier height)

Test results

see tables and graphs in Section C.5

Single-number ratings

The single-number ratings for the airborne sound insulation amount to:

$DL_{SI,E}$ = 36 dB (element)	Category: D3
$DL_{SI,P}$ = 31 dB (post)	Category: D3
$DL_{SI,G}$ = 33 dB (global)	Category: D3

C.3 Test Setup

The barrier under test is a single-leaf, reflective engineered timber traffic noise barrier. Each element is 2.4m wide x 4.2m high, supported by I-section posts which are at 2.4m centres. The section of barrier under test is situated on the northern side of SH18. Figure C.1 shows the traffic noise barrier viewed from the road-side.

Figure C.1 General view of the traffic noise barrier under test (road-side), the crosses mark the measurement positions. Image from Google Maps

The crosses in Figure C.1 show the approximate positions of the loudspeaker/centre microphone axis. The measurement points are on the rear-side of the barrier, on a vertical measurement grid of 3 x 3 points with equal horizontal and vertical distances of 0.40m. This measurement grid was located horizontally in the middle of an element (element measurement) and in front of a post (post measurement). The loudspeaker/centre microphone height was 2.1m below the barrier top.

The barrier thickness at the height of measurement is 32mm.

The Adrienne temporal window length has been chosen to exclude any parasitic reflections that may otherwise affect the measurement results.

The loudspeaker and microphone array are shown in Figure C.2 and C.3, respectively.

Figure C.2 Test arrangement showing the loudspeaker when measuring across an element

Figure C.3 Test arrangement showing the microphone array when measuring across an element

C.4 Test Object

Figure C.4 shows the composition of the engineered timber traffic noise barrier. Each element of the barrier is constructed from several horizontal panels. The horizontal panels are clamped in the I-section posts with a length of right angle section as shown in Figure C.4.

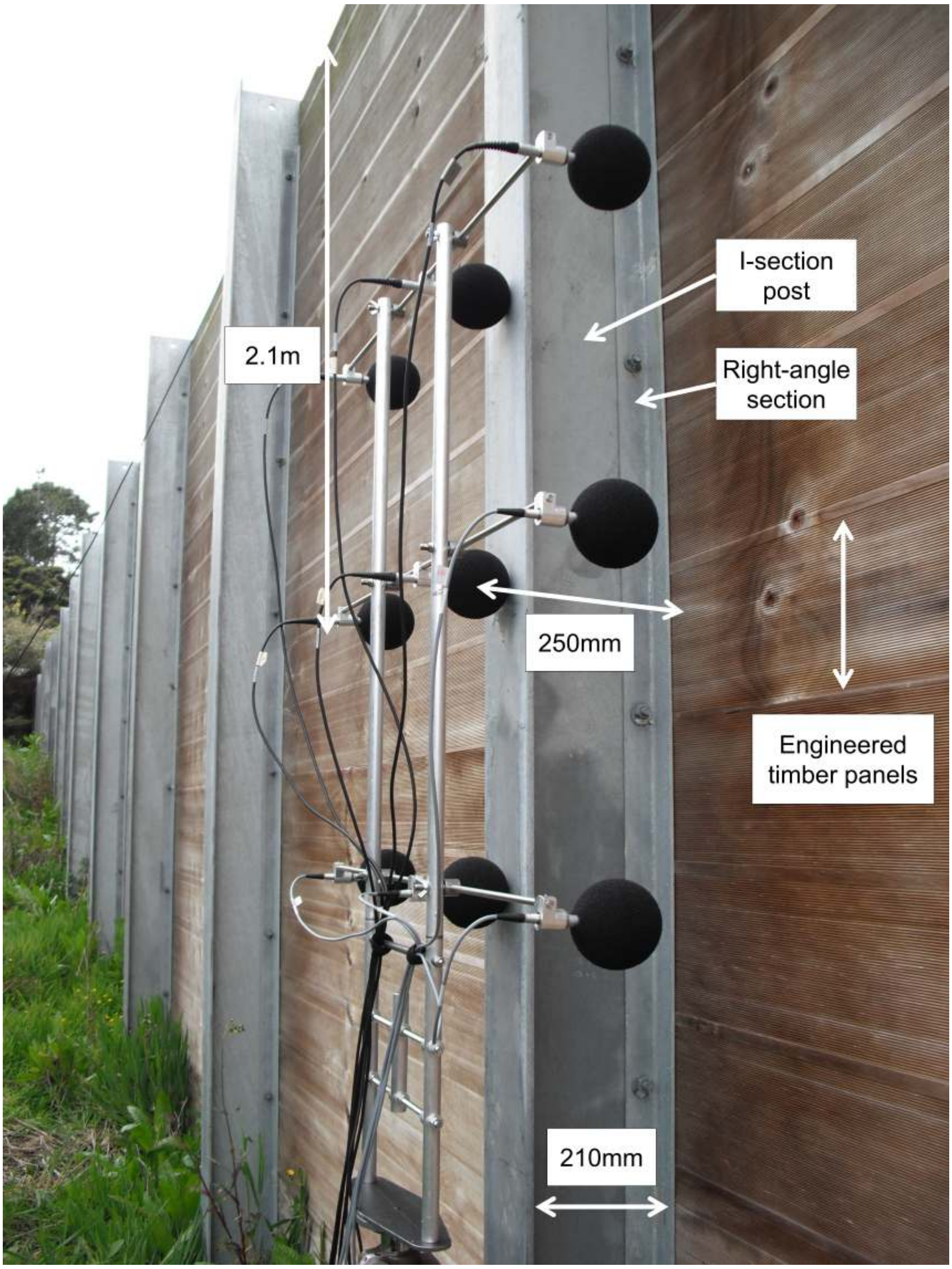

Figure C.4 Composition of the engineered timber traffic noise barrier, test setup during a post measurement

C.5 Results

C.5.1 Results for Barrier Element

Table C.1 Airborne sound insulation values at nine microphone positions and logarithmic average for the element measurement, highlighted values are below the low frequency limit

Microphone Positions	*One-third Octave Band Centre Frequency (Hz)* 160	200	250	315	400	500	630	800	1k	1.25k	1.6k	2k	2.5k	3.15k	4k	5k
SI_1	23.5	24.7	26.2	28.1	30.8	33.8	35.2	36.8	40.5	41.4	43.8	43.5	45.3	44.0	43.2	47.1
SI_2	24.6	25.4	26.8	29.1	32.3	34.5	35.5	37.5	38.6	41.1	41.8	45.8	46.5	46.5	43.9	46.4
SI_3	25.1	25.7	26.9	28.8	31.5	34.0	35.4	37.5	38.5	38.6	40.4	44.5	45.3	44.6	44.8	41.5
SI_4	24.7	25.4	26.6	28.6	31.5	34.6	35.5	37.0	39.0	40.8	43.5	43.6	44.4	44.6	49.6	49.0
SI_5	24.3	25.2	26.7	29.1	32.4	34.8	34.8	37.0	39.3	42.7	44.6	45.5	47.2	46.9	52.2	50.2
SI_6	25.3	26.0	27.0	28.6	30.9	33.7	35.3	36.3	37.7	40.2	44.7	43.3	43.2	42.5	42.2	38.3
SI_7	25.2	25.8	26.7	28.1	30.4	33.5	35.4	36.4	38.7	40.2	42.1	44.1	47.9	47.3	47.2	51.7
SI_8	25.2	25.8	27.0	28.8	31.3	33.5	34.4	36.2	38.7	40.8	43.6	46.2	46.7	50.4	46.6	51.0
SI_9	25.2	25.8	26.8	28.4	30.6	33.3	35.1	35.8	37.6	38.4	41.4	46.6	52.8	46.8	46.4	47.1
Average	24.2	25.0	26.2	28.1	30.7	33.4	34.7	36.2	38.1	39.8	42.1	44.1	45.5	45.0	44.8	44.0

Single number rating of the airborne sound insulation across an element, $DL_{SI,E}$ = 36 dB, with a low frequency limit of 315 Hz.

C.5.2 Results for Barrier Post

Table C.2 Airborne sound insulation values at nine microphone positions and logarithmic average for the post measurement, highlighted values are below the low frequency limit

Microphone Positions	*One-third Octave Band Centre Frequency (Hz)* 160	200	250	315	400	500	630	800	1k	1.25k	1.6k	2k	2.5k	3.15k	4k	5k
SI_1	22.9	22.9	22.9	23.1	23.9	25.9	29.5	33.1	37.7	33.0	39.7	40.4	40.1	36.3	30.1	34.7
SI_2	25.9	26.1	26.3	26.5	26.6	26.5	27.0	28.9	35.2	38.8	49.0	45.7	53.9	51.8	46.0	49.9
SI_3	27.0	27.4	28.1	29.3	31.1	33.9	35.8	36.2	43.1	37.0	41.4	41.7	45.2	47.8	40.9	44.4
SI_4	21.7	22.0	22.7	23.5	24.5	26.0	28.3	29.6	30.7	34.7	40.8	42.7	38.5	36.4	26.2	26.2
SI_5	27.1	26.9	26.8	26.7	26.8	27.0	27.4	28.0	33.3	46.4	52.0	49.3	52.5	53.5	49.7	52.8
SI_6	27.4	27.9	28.7	30.1	32.5	35.5	34.9	34.1	40.9	38.4	42.5	42.8	46.9	49.7	36.9	37.2
SI_7	21.6	21.9	22.5	23.5	25.1	27.8	31.3	34.4	32.3	30.9	39.0	36.4	31.2	27.2	23.1	31.8
SI_8	26.5	26.6	26.9	27.5	28.3	29.4	30.0	29.1	30.1	37.2	41.9	43.1	40.5	43.2	40.3	51.4
SI_9	27.3	27.9	29.0	30.9	33.9	36.8	33.9	30.6	35.4	40.8	42.6	41.0	45.5	42.0	41.3	49.8
Average	24.1	24.3	24.8	25.4	26.4	27.9	29.4	30.2	33.3	35.2	41.4	40.8	38.3	35.0	29.6	33.4

Single number rating of the airborne sound insulation across a post, $DL_{SI,P}$ = 31 dB, with a low frequency limit of 315 Hz.

C.5.3 Results for Barrier Global

Table C.3 Airborne sound insulation values at nine microphone positions and logarithmic average for the global measurement, highlighted values are below the low frequency limit

Microphone	*One-third Octave Band Centre Frequency (Hz)*															
Positions	160	200	250	315	400	500	630	800	1k	1.25k	1.6k	2k	2.5k	3.15k	4k	5k
SI_1	23.2	23.7	24.3	25.0	26.1	28.2	31.5	34.5	38.8	35.4	41.3	41.7	42.0	38.7	32.9	37.5
SI_2	25.2	25.7	26.6	27.7	28.5	28.9	29.4	31.4	36.5	39.8	44.0	45.8	48.8	48.4	44.8	47.8
SI_3	26.0	26.5	27.5	29.0	31.3	33.9	35.6	36.8	40.2	37.7	40.9	42.9	45.2	45.9	42.4	42.7
SI_4	22.9	23.4	24.2	25.3	26.8	28.5	30.6	31.9	33.1	36.8	42.0	43.1	40.5	38.8	29.1	29.2
SI_5	25.5	26.0	26.8	27.7	28.7	29.3	29.7	30.5	35.4	44.1	46.9	47.0	49.1	49.0	50.8	51.3
SI_6	26.2	26.8	27.8	29.3	31.6	34.5	35.1	35.1	39.0	39.2	43.5	43.0	44.7	44.8	38.8	37.7
SI_7	23.0	23.4	24.1	25.2	27.0	29.8	32.9	35.3	34.4	33.4	40.3	38.8	34.1	30.1	26.1	34.8
SI_8	25.8	26.2	27.0	28.1	29.5	31.0	31.7	31.3	32.6	38.7	42.7	44.4	42.6	45.5	42.4	51.2
SI_9	26.1	26.7	27.8	29.4	32.0	34.7	34.4	32.5	36.4	39.5	41.9	42.9	47.7	43.7	43.1	48.2
Average	24.7	25.2	25.9	27.1	28.6	30.3	31.8	32.8	35.6	37.4	42.3	42.7	41.1	38.1	33.0	36.6

Single number rating for the global airborne sound insulation, $DL_{SI,G}$ = 33 dB, with a low frequency limit of 315 Hz.

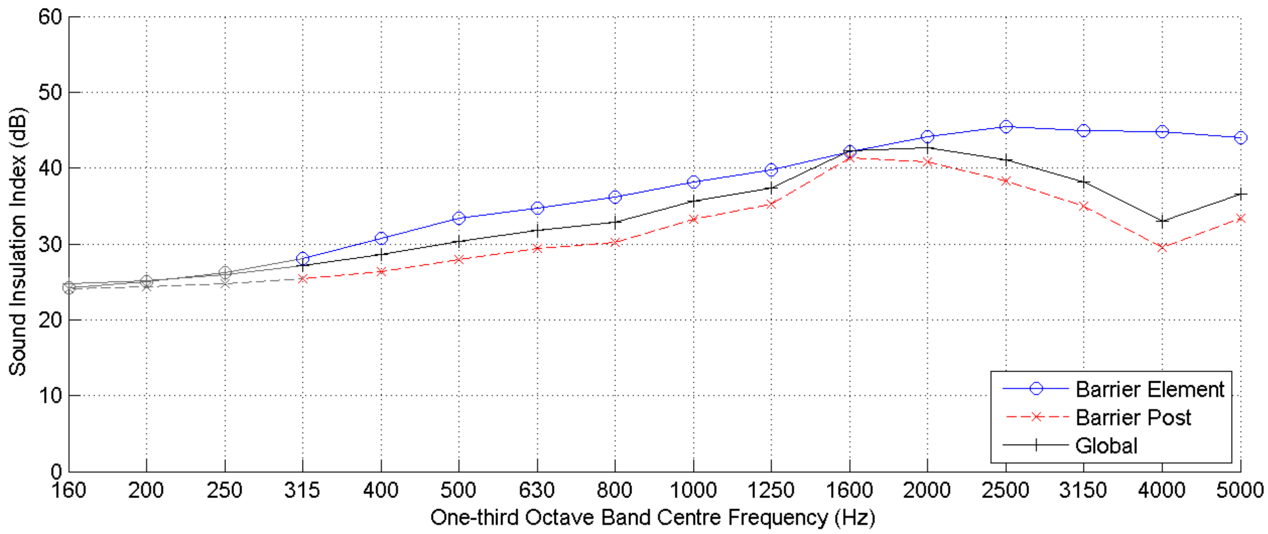

Figure C.5 Airborne sound insulation values, logarithmically averaged over nine microphone positions. The grey lines represent values below the low frequency limit of the measurement.

Appendix D

Airborne Sound Insulation of the 2.9m Engineered Timber Barrier at Maioro Street

D.1 Introduction

The tests described in this report were conducted on 26 October 2012. The tests were performed at the request of the NZ Transport Agency (NZTA) to determine the airborne sound insulation of the engineered timber traffic noise barrier at Maioro Street.

The tests were performed in accordance with the draft European standard EN1793-6:2011 *Road traffic noise reducing devices - Test method for determining the acoustic performance - Part 6: Intrinsic characteristics - In situ values of airborne sound insulation under direct sound field conditions*.

D.2 Test Summary

Name and address of testing organisation:
Acoustics Research Group
University of Canterbury
Christchurch 8041
New Zealand

Test Date:
26 October 2012
Test Location:
Maioro Street

Test Setup:
see description and photographic presentation in Section D.3

Test Object:

Manufacturer:	Nuibarrier
Type:	engineered timber
Dimensions:	2.9m high, 2.6m wide, 32mm thick
Date of installation:	2011
Physical condition during test (visual inspection):	good
Composition:	see description and photographic presentation in Section D.4

Meteorological conditions prevailing during the test:

Wind speed:	1.3 m/s
Air temperature:	22.7 °C
Air pressure:	100.10 kPa
Relative Humidity:	65.6 %

Test arrangement:
see description and photographic presentation in Section D.3

Equipment used for measurement and analysis:

Sound source

Description:	single driver (12 inch diameter, 600W) sealed loudspeaker, enclosure dimensions: 400mm x 400mm x 450mm

Microphones

Manufacturer:	Bruel & Kjaer
Type:	Type 4189 (1/2" pre-polarised, free-field) Type 2669-C preamplifier (microphones 1-5) Type 2669-L preamplifier (microphones 6-9)
Serial numbers:	2573559 (microphone 1) 2573560 (microphone 2) 2573563 (microphone 3) 2573562 (microphone 4) 2573561 (microphone 5) 2626749 (microphone 6) 2593736 (microphone 7) 2674393 (microphone 8) 2674394 (microphone 9)

Analyser

Manufacturer:	Bruel & Kjaer
Type:	Type 7539 (5 channels)
Serial number:	2472233

Filtering and sampling

Anti-aliasing filter type:	3rd order Butterworth
Sample rate:	65,536 Hz

Adrienne temporal window

Length:	4.5 ms (barrier element) 4.5 ms (barrier post)

Test frequency range

Low frequency limit:	315 Hz (barrier element), 315 Hz (barrier post)
Smallest dimension:	2.9m (barrier height)

Test results

see tables and graphs in Section D.5

Single-number ratings

The single-number ratings for the airborne sound insulation amount to:

$DL_{SI,E}$ = 36 dB (element)	Category: D3
$DL_{SI,P}$ = 35 dB (post)	Category: D3
$DL_{SI,G}$ = 35 dB (global)	Category: D3

D.3 Test Setup

The barrier under test is a single-leaf, reflective engineered timber traffic noise barrier. Each element is 2.6m wide x 2.9m high, supported by I-section posts which are at 2.6m centres. The section of barrier under test is situated at the eastern end of Ernie Pinches Street . Figure D.1 shows the traffic noise barrier viewed from the road-side.

Figure D.1 General view of the traffic noise barrier under test (road-side), the crosses mark the measurement positions

The crosses in Figure D.1 show the approximate positions of the loudspeaker/centre microphone axis. The measurement points are on the rear-side of the barrier, on a vertical measurement grid of 3 x 3 points with equal horizontal and vertical distances of 0.40m. This measurement grid was located horizontally in the middle of an element (element measurement) and in front of a post (post measurement). The loudspeaker/centre microphone height was 1.25m below the barrier top.

The barrier thickness at the height of measurement is 32mm.

The Adrienne temporal window length has been chosen to exclude any parasitic reflections that may otherwise affect the measurement results.

The loudspeaker and microphone array are shown in Figure D.2 and D.3, respectively.

Figure D.2 Test arrangement showing the loudspeaker when measuring across a post

Figure D.3 Test arrangement showing the microphone array when measuring across an element

D.4 Test Object

Figure D.4 shows the composition of the engineered timber traffic noise barrier. Each element of the barrier is constructed from several horizontal panels. The horizontal panels are clamped in the I-section posts with a length of right angle section as shown in Figure D.4.

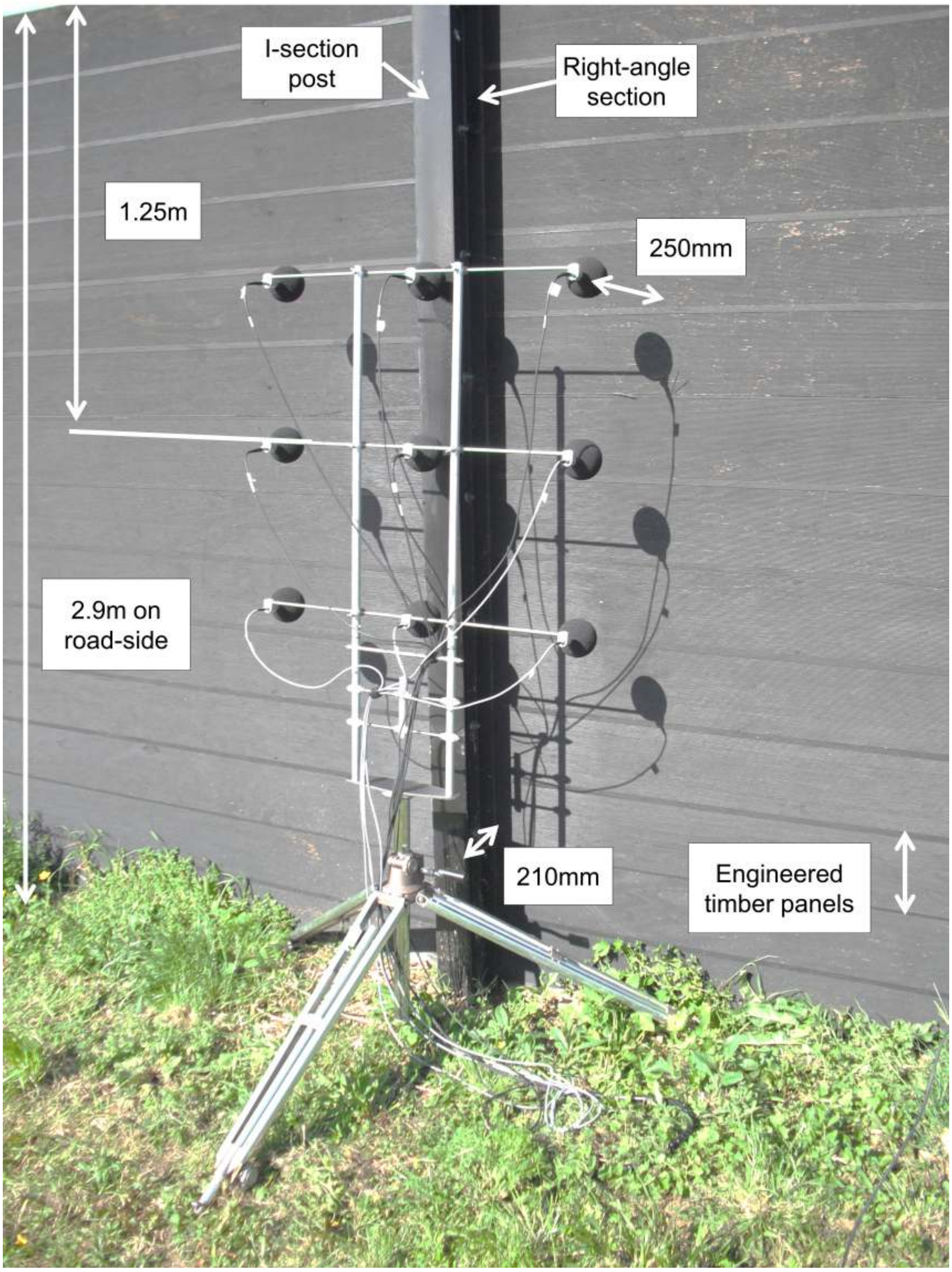

Figure D.4 Composition of the engineered timber traffic noise barrier, test setup during a post measurement

D.5 Results

D.5.1 Results for Barrier Element

Table D.1 Airborne sound insulation values at nine microphone positions and logarithmic average for the element measurement, highlighted values are below the low frequency limit

Microphone	*One-third Octave Band Centre Frequency (Hz)*															
Positions	160	200	250	315	400	500	630	800	1k	1.25k	1.6k	2k	2.5k	3.15k	4k	5k
SI_1	31.1	32.2	33.9	36.4	38.5	38.3	37.9	37.2	35.6	35.7	34.9	34.8	39.9	41.1	45.8	50.1
SI_2	30.8	31.4	32.7	35.3	40.8	43.6	35.2	32.8	37.3	30.3	36.5	33.1	38.3	47.4	43.0	48.0
SI_3	31.2	31.3	31.7	32.8	35.2	40.1	38.9	33.0	38.6	32.1	38.2	36.4	37.2	37.6	41.5	44.9
SI_4	30.7	31.9	34.0	37.5	39.9	38.4	39.4	38.1	34.0	40.0	39.3	36.1	38.3	44.3	47.9	47.5
SI_5	29.3	30.1	31.9	35.6	43.6	39.1	34.0	35.9	34.4	32.6	41.7	39.9	42.9	46.7	55.3	51.8
SI_6	31.0	33.2	36.2	39.8	39.3	35.5	33.8	37.3	38.5	39.0	34.3	33.6	37.6	40.4	43.6	53.8
SI_7	28.8	31.4	34.9	39.1	39.9	36.3	34.6	40.3	34.3	35.9	33.1	37.9	44.5	40.8	46.5	48.8
SI_8	30.5	34.2	38.2	39.4	38.4	38.1	38.4	39.1	38.1	34.8	37.0	31.9	40.4	44.2	46.6	50.5
SI_9	31.3	34.6	37.4	37.9	37.2	37.2	38.4	40.0	37.2	34.3	32.4	35.1	41.5	41.8	43.5	46.5
Average	29.9	31.5	33.5	36.0	38.2	37.5	35.7	35.7	35.6	33.5	35.0	34.3	39.0	41.2	44.3	47.9

Single number rating of the airborne sound insulation across an element, $DL_{SI,E}$ = 36 dB, with a low frequency limit of 315 Hz.

D.5.2 Results for Barrier Post

Table D.2 Airborne sound insulation values at nine microphone positions and logarithmic average for the post measurement, highlighted values are below the low frequency limit

Microphone	*One-third Octave Band Centre Frequency (Hz)*															
Positions	160	200	250	315	400	500	630	800	1k	1.25k	1.6k	2k	2.5k	3.15k	4k	5k
SI_1	29.2	29.7	30.9	33.5	39.0	41.8	33.8	31.4	39.1	35.7	36.1	41.9	42.9	40.6	47.8	44.5
SI_2	32.5	32.1	30.5	29.3	29.2	30.8	35.2	39.6	36.3	35.3	38.0	40.0	45.2	45.2	45.6	49.1
SI_3	24.6	25.8	27.3	29.4	33.1	41.1	40.9	39.6	32.7	31.5	35.1	34.5	36.7	45.6	41.9	40.8
SI_4	30.3	31.0	32.4	35.1	39.1	39.5	36.5	39.0	32.7	28.2	37.1	41.0	40.6	46.2	41.4	50.7
SI_5	29.4	29.6	30.1	31.4	33.7	37.1	39.8	42.9	39.4	33.3	38.8	41.4	53.2	54.4	55.2	54.2
SI_6	28.5	29.0	30.0	32.1	36.5	44.0	35.1	30.1	31.9	35.0	38.0	37.2	44.0	42.2	46.9	48.9
SI_7	29.9	30.9	32.0	33.6	36.5	42.3	44.0	37.6	33.3	29.7	34.6	34.9	35.5	42.5	38.2	46.4
SI_8	30.9	31.0	31.4	32.4	34.6	39.2	49.4	44.7	43.3	40.2	43.9	39.9	49.2	57.5	55.7	50.5
SI_9	26.7	27.9	30.3	35.4	45.8	35.8	32.5	35.7	38.5	35.7	32.8	40.2	39.3	40.3	44.9	39.3
Average	28.0	28.7	29.8	31.5	34.0	36.6	35.9	34.9	34.5	32.0	35.8	37.6	39.8	43.2	43.1	44.2

Single number rating of the airborne sound insulation across a post, $DL_{SI,P}$ = 35 dB, with a low frequency limit of 315 Hz.

D.5.3 Results for Barrier Global

Table D.3 Airborne sound insulation values at nine microphone positions and logarithmic average for the global measurement, highlighted values are below the low frequency limit

Microphone	*One-third Octave Band Centre Frequency (Hz)*															
Positions	160	200	250	315	400	500	630	800	1k	1.25k	1.6k	2k	2.5k	3.15k	4k	5k
SI_1	30.0	30.7	32.1	34.7	38.8	39.7	35.4	33.4	37.0	35.7	35.5	37.0	41.2	40.8	46.7	46.4
SI_2	31.5	31.7	31.4	31.3	31.9	33.6	35.2	34.9	36.7	32.1	37.2	35.3	40.5	46.2	44.1	48.6
SI_3	26.7	27.7	28.9	30.8	34.0	40.5	39.8	35.1	34.7	31.8	36.4	35.4	36.9	40.0	41.7	42.4
SI_4	30.5	31.4	33.2	36.2	39.5	38.9	37.7	38.5	33.3	31.0	38.1	37.9	39.3	45.2	43.5	48.8
SI_5	29.3	29.8	30.9	33.0	36.3	38.0	36.0	38.1	36.3	32.9	40.0	40.6	45.5	49.0	55.3	52.8
SI_6	29.6	30.6	32.1	34.4	37.7	38.0	34.4	32.4	34.0	36.5	35.7	35.0	39.7	41.2	44.9	50.7
SI_7	29.3	31.2	33.2	35.5	37.9	38.3	37.1	38.7	33.7	31.8	33.8	36.2	38.0	41.5	40.6	47.4
SI_8	30.7	32.3	33.6	34.6	36.1	38.6	41.1	41.0	40.0	36.7	39.2	34.2	42.9	47.0	49.1	50.5
SI_9	28.4	30.0	32.5	36.5	39.7	36.4	34.5	37.4	37.8	34.9	32.6	36.9	40.3	41.0	44.1	41.6
Average	29.4	30.4	31.8	33.7	36.1	37.5	36.3	35.8	35.5	33.2	35.9	36.2	39.9	42.6	44.2	46.2

Single number rating for the global airborne sound insulation, $DL_{SI,G}$ = 35 dB, with a low frequency limit of 315 Hz.

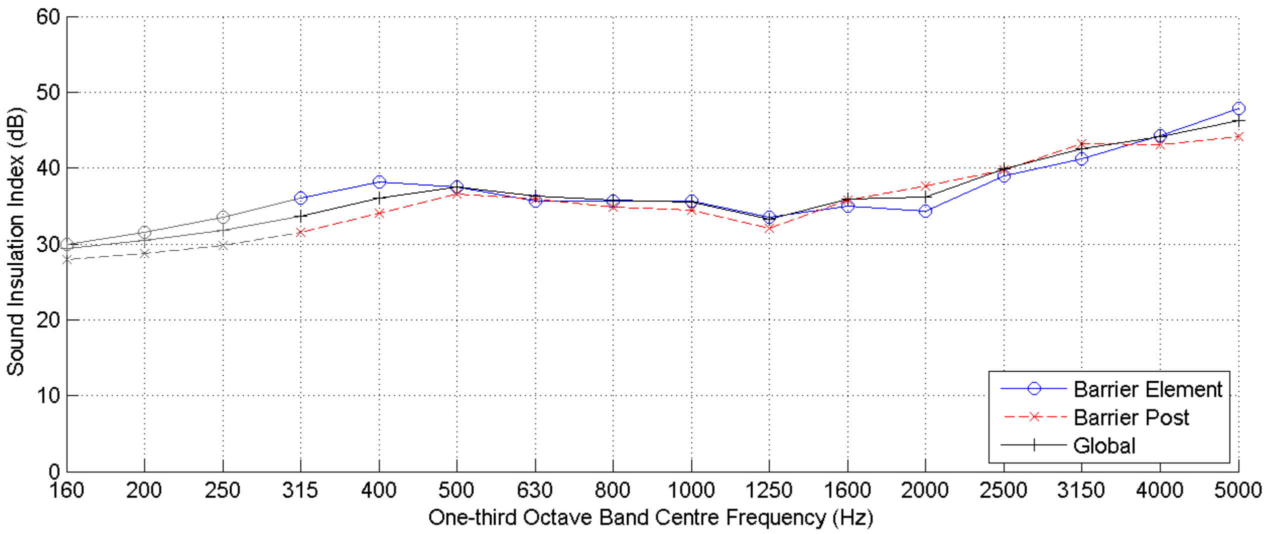

Figure D.5 Airborne sound insulation values, logarithmically averaged over nine microphone positions. The grey lines represent values below the low frequency limit of the measurement.

Appendix E

Airborne Sound Insulation of the 3.2m Concrete Barrier at Maioro Street

E.1 Introduction

The tests described in this report were conducted on 24 October 2012. The tests were performed at the request of the NZ Transport Agency (NZTA) to determine the airborne sound insulation of the concrete traffic noise barrier at Maioro Street.

The tests were performed in accordance with the draft European standard EN1793-6:2011 *Road traffic noise reducing devices - Test method for determining the acoustic performance - Part 6: Intrinsic characteristics - In situ values of airborne sound insulation under direct sound field conditions*.

E.2 Test Summary

Name and address of testing organisation:
Acoustics Research Group
University of Canterbury
Christchurch 8041
New Zealand

Test Date:
24 October 2012
Test Location:
Maioro Street

Test Setup:
see description and photographic presentation in Section E.3

Test Object:

Manufacturer:	unknown
Type:	concrete
Dimensions:	3.2m high, 2.5m wide, ~120mm thick
Date of installation:	2011
Physical condition during test (visual inspection):	good
Composition:	see description and photographic presentation in Section E.4

Meteorological conditions prevailing during the test:

Wind speed:	1.2 m/s
Air temperature:	20.6 °C
Air pressure:	101.90 kPa
Relative Humidity:	35.9 %

Test arrangement:
see description and photographic presentation in Section E.3

Equipment used for measurement and analysis:

Sound source

Description:	single driver (12 inch diameter, 600W) sealed loudspeaker, enclosure dimensions: 400mm x 400mm x 450mm

Microphones

Manufacturer:	Bruel & Kjaer
Type:	Type 4189 (1/2" pre-polarised, free-field) Type 2669-C preamplifier (microphones 1-5) Type 2669-L preamplifier (microphones 6-9)
Serial numbers:	2573559 (microphone 1) 2573560 (microphone 2) 2573563 (microphone 3) 2573562 (microphone 4) 2573561 (microphone 5) 2626749 (microphone 6) 2593736 (microphone 7) 2674393 (microphone 8) 2674394 (microphone 9)

Analyser

Manufacturer:	Bruel & Kjaer
Type:	Type 7539 (5 channels)
Serial number:	2472233

Filtering and sampling

Anti-aliasing filter type:	3rd order Butterworth
Sample rate:	65,536 Hz

Adrienne temporal window

Length:	5.5 ms (barrier element) 5.5 ms (barrier post)

Test frequency range

Low frequency limit:	250 Hz (barrier element), 250 Hz (barrier post)
Smallest dimension:	3.2m (barrier height)

Test results

see tables and graphs in Section E.5

Single-number ratings

The single-number ratings for the airborne sound insulation amount to:

$DL_{SI,E}$ = 65 dB (element)	Category: D4
$DL_{SI,P}$ = 66 dB (post)	Category: D4
$DL_{SI,G}$ = 65 dB (global)	Category: D4

E.3 Test Setup

The barrier under test is a single-leaf, reflective concrete traffic noise barrier constructed of single panels. Each element is 2.5m wide x 3.2m high and is supported by I-section posts. The section of barrier under test is situated on the Maioro Street boundary of Christ the King School. Figure E.1 shows the traffic noise barrier viewed from the road-side.

The measurement points are on the rear-side of the barrier, on a vertical measurement grid of 3 x 3 points with equal horizontal and vertical distances of 0.40m. This measurement grid was located horizontally in the middle of an element (element measurement) and in front of an I-section post (post measurement). The loudspeaker/centre microphone height was 1.55m below the barrier top.

The barrier thickness at the height of measurement is ~120mm.

The Adrienne temporal window length has been chosen to exclude any parasitic reflections that may otherwise affect the measurement results.

The loudspeaker and microphone array are shown in Figure E.1 and E.2, respectively.

Figure E.1 Test arrangement showing the loudspeaker when measuring across a post

Figure E.2 Test arrangement showing the microphone array when measuring across an element

E.4 Test Object

Figure E.3 shows the composition of the concrete traffic noise barrier. Each element of the barrier is constructed from a 2.5m wide solid concrete slab. The barrier elements are supported by the I-section posts.

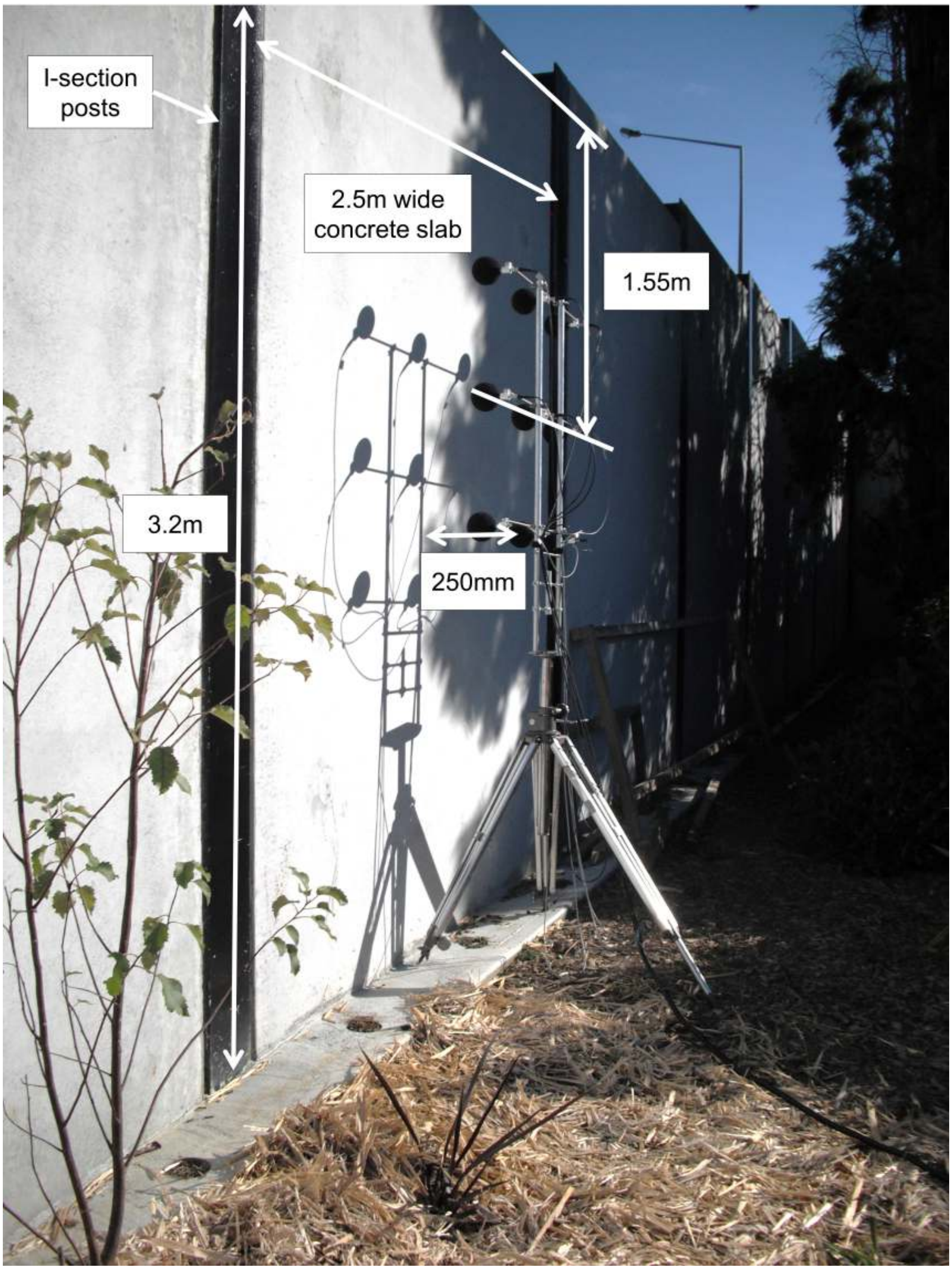

Figure E.3 Composition of the concrete traffic noise barrier, test setup during an element measurement

E.5 Results

E.5.1 Results for Barrier Element

Table E.1 Airborne sound insulation values at nine microphone positions and logarithmic average for the element measurement, highlighted values are below the low frequency limit

Microphone Positions	160	200	250	315	400	500	630	800	1k	1.25k	1.6k	2k	2.5k	3.15k	4k	5k
SI_1	43.7	46.1	49.1	52.7	57.3	62.1	60.8	64.3	66.1	66.2	67.8	70.6	72.9	69.2	57.0	60.6
SI_2	52.9	53.6	54.6	56.6	61.3	72.1	72.1	69.6	72.9	68.9	73.2	79.1	75.3	77.3	64.3	60.1
SI_3	41.8	47.5	56.5	64.7	67.6	63.3	64.1	68.7	67.4	67.2	68.4	70.3	69.9	69.6	56.5	58.3
SI_4	46.9	51.6	58.1	64.2	64.7	66.6	74.8	70.6	71.1	71.2	73.2	75.7	79.4	78.0	66.3	62.6
SI_5	46.7	51.2	57.6	68.5	69.2	68.3	73.8	70.9	73.9	74.0	77.3	80.0	82.2	83.3	78.5	73.6
SI_6	49.7	54.1	58.3	59.7	61.1	66.4	67.8	73.0	88.6	77.1	73.7	76.5	81.5	78.8	85.4	75.6
SI_7	48.8	51.6	54.8	59.7	63.9	60.0	62.1	74.2	77.8	71.8	72.6	77.0	79.9	75.5	74.5	75.2
SI_8	50.3	53.8	58.1	64.8	66.8	62.4	65.8	73.2	77.8	70.7	75.3	76.7	81.9	82.1	76.2	69.8
SI_9	49.2	52.8	57.7	63.5	62.9	62.0	66.9	75.7	81.0	70.4	73.3	76.2	84.3	75.8	74.4	74.5
Average	46.0	49.9	54.4	58.5	61.9	63.1	64.9	69.3	71.0	69.3	71.3	74.0	75.5	73.7	62.1	62.9

Single number rating of the airborne sound insulation across an element, $DL_{SI,E}$ = 65 dB, with a low frequency limit of 250 Hz.

E.5.2 Results for Barrier Post

Table E.2 Airborne sound insulation values at nine microphone positions and logarithmic average for the post measurement, highlighted values are below the low frequency limit

Microphone Positions	160	200	250	315	400	500	630	800	1k	1.25k	1.6k	2k	2.5k	3.15k	4k	5k
SI_1	56.7	62.4	54.9	52.9	54.7	61.7	69.6	71.7	70.4	72.1	73.2	71.2	70.4	64.5	61.5	59.4
SI_2	53.8	58.9	67.1	73.7	65.1	64.0	65.5	65.1	64.5	69.4	74.1	70.6	73.3	67.6	66.0	57.6
SI_3	48.4	56.6	64.7	57.9	58.4	64.1	68.2	66.1	68.0	69.5	66.4	69.1	67.1	73.0	58.8	55.5
SI_4	57.1	58.7	60.0	61.4	63.3	66.3	72.7	72.1	73.3	72.0	74.1	72.4	73.9	73.9	65.8	62.6
SI_5	58.4	61.4	66.8	77.2	67.5	64.8	66.4	68.5	76.9	73.4	76.2	81.5	74.1	78.6	79.1	73.5
SI_6	56.4	66.1	60.2	58.3	62.2	70.0	64.4	71.5	71.8	68.1	76.1	75.9	81.1	75.9	75.9	71.0
SI_7	52.4	55.3	60.7	70.9	72.3	71.0	63.4	67.4	70.7	71.7	73.6	80.2	73.3	73.1	66.1	74.5
SI_8	52.4	54.7	58.5	64.9	73.3	68.6	66.4	74.8	71.6	68.6	73.4	76.7	71.6	71.4	70.3	65.4
SI_9	53.4	57.4	57.8	57.9	62.4	67.8	62.1	68.7	73.4	73.7	74.5	72.7	76.7	76.1	69.7	72.8
Average	52.7	57.4	59.1	58.6	60.6	65.0	65.0	68.1	69.3	70.0	71.8	72.4	71.6	70.0	64.2	60.7

Single number rating of the airborne sound insulation across a post, $DL_{SI,P}$ = 66 dB, with a low frequency limit of 250 Hz.

E.5.3 Results for Barrier Global

Table E.3 Airborne sound insulation values at nine microphone positions and logarithmic average for the global measurement, highlighted values are below the low frequency limit

Microphone	*One-third Octave Band Centre Frequency (Hz)*															
Positions	160	200	250	315	400	500	630	800	1k	1.25k	1.6k	2k	2.5k	3.15k	4k	5k
SI_1	46.5	49.1	51.1	52.8	55.8	61.9	63.3	66.6	67.8	68.2	69.7	70.9	71.5	66.3	58.7	60.0
SI_2	53.3	55.5	57.4	59.6	62.8	66.4	67.7	66.8	66.9	69.2	73.6	73.0	74.2	70.2	65.1	58.7
SI_3	44.0	50.0	58.9	60.1	60.9	63.7	65.6	67.2	67.7	68.2	67.3	69.7	68.3	71.0	57.5	56.7
SI_4	49.5	53.8	58.9	62.6	64.0	66.5	73.6	71.3	72.1	71.6	73.6	73.7	75.8	75.5	66.0	62.6
SI_5	49.5	53.8	60.1	71.0	68.3	66.2	68.7	69.5	75.1	73.7	76.7	80.7	76.5	80.4	78.8	73.6
SI_6	51.9	56.8	59.2	59.0	61.6	67.9	65.8	72.2	74.7	70.6	74.8	76.2	81.3	77.1	78.5	72.7
SI_7	50.3	53.0	56.8	62.4	66.4	62.6	62.7	69.6	72.9	71.7	73.1	78.3	75.4	74.1	68.5	74.8
SI_8	51.2	54.2	58.3	64.8	68.9	64.5	66.1	74.0	73.7	69.5	74.3	76.7	74.2	74.0	72.3	67.1
SI_9	50.8	54.5	57.8	59.9	62.7	64.0	63.8	70.9	75.8	71.8	73.8	74.1	79.0	76.0	71.4	73.5
Average	48.7	52.7	56.6	59.1	61.7	64.4	65.5	69.1	70.6	70.2	72.0	73.6	73.6	72.0	63.5	62.2

Single number rating for the global airborne sound insulation, $DL_{SI,G}$ = 65 dB, with a low frequency limit of 250 Hz.

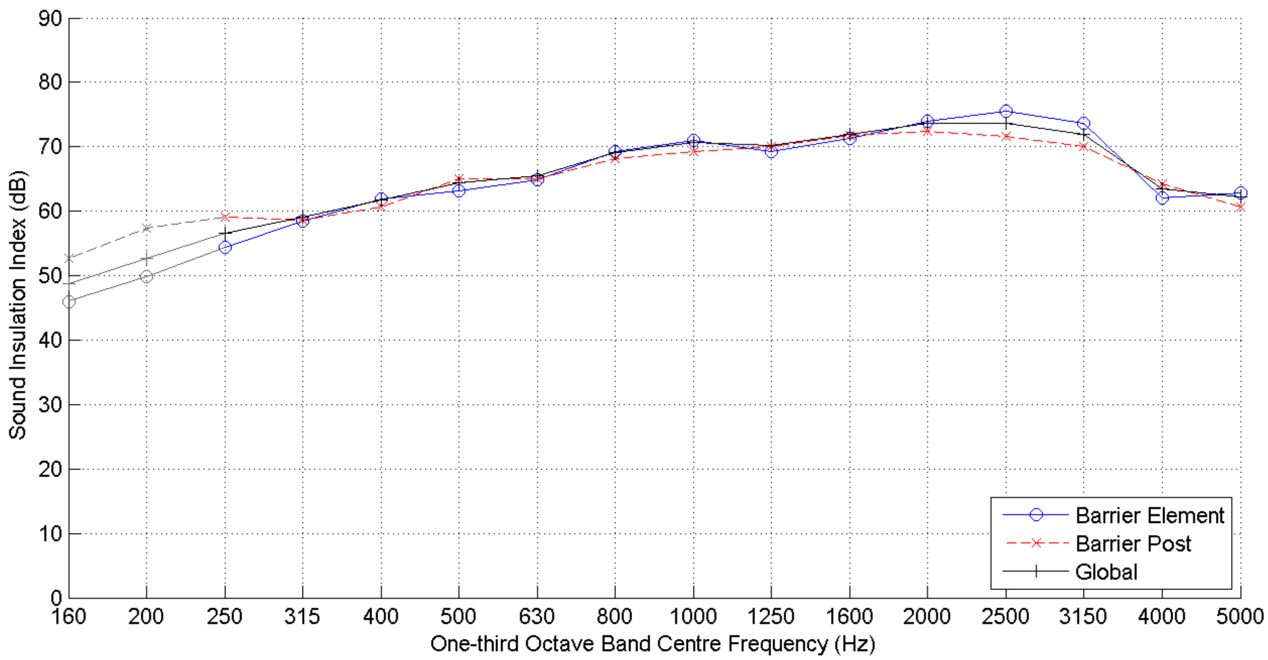

Figure E.4 Airborne sound insulation values, logarithmically averaged over nine microphone positions. The grey lines represent values below the low frequency limit of the measurement.

Appendix F

Airborne Sound Insulation of the 3.9m Plywood Barrier at Hobsonville

F.1 Introduction

The tests described in this report were conducted on 25 October 2012. The tests were performed at the request of the NZ Transport Agency (NZTA) to determine the airborne sound insulation of the plywood barrier at Hobsonville.

The tests were performed in accordance with the draft European standard EN1793-6:2011 *Road traffic noise reducing devices - Test method for determining the acoustic performance - Part 6: Intrinsic characteristics - In situ values of airborne sound insulation under direct sound field conditions*.

F.2 Test Summary

Name and address of testing organisation:
Acoustics Research Group
University of Canterbury
Christchurch 8041
New Zealand

Test Date:
25 October 2012
Test Location:
Hobsonville

Test Setup:
see description and photographic presentation in Section F.3

Test Object:

Manufacturer:	unknown
Type:	plywood
Dimensions:	3.9m high, 2.4m wide, ~20mm thick
Date of installation:	2011
Physical condition during test (visual inspection):	small gaps between sheets
Composition:	see description and photographic presentation in Section F.4

Meteorological conditions prevailing during the test:

Wind speed:	1.0 m/s
Air temperature:	22 °C
Air pressure:	100.40 kPa
Relative Humidity:	41.5 %

Test arrangement:
see description and photographic presentation in Section F.3

Equipment used for measurement and analysis:

Sound source

Description:	single driver (12 inch diameter, 600W) sealed loudspeaker, enclosure dimensions: 400mm x 400mm x 450mm

Microphones

Manufacturer:	Bruel & Kjaer
Type:	Type 4189 (1/2" pre-polarised, free-field) Type 2669-C preamplifier (microphones 1-5) Type 2669-L preamplifier (microphones 6-9)
Serial numbers:	2573559 (microphone 1) 2573560 (microphone 2) 2573563 (microphone 3) 2573562 (microphone 4) 2573561 (microphone 5) 2626749 (microphone 6) 2593736 (microphone 7) 2674393 (microphone 8) 2674394 (microphone 9)

Analyser

Manufacturer:	Bruel & Kjaer
Type:	Type 7539 (5 channels)
Serial number:	2472233

Filtering and sampling

Anti-aliasing filter type:	3rd order Butterworth
Sample rate:	65,536 Hz

Adrienne temporal window

Length:	7.9 ms (barrier element 1) 7.9 ms (barrier element 2)

Test frequency range

Low frequency limit:	160 Hz (barrier element 1), 160 Hz (barrier element 2)
Smallest dimension:	3.9m (barrier height)

Test results

see tables and graphs in Section F.5

Single-number ratings

The single-number ratings for the airborne sound insulation amount to:

$DL_{SI,E1}$ = 29 dB (element)	Category: D3
$DL_{SI,E2}$ = 29 dB (element)	Category: D3
$DL_{SI,G}$ = 29 dB (global)	Category: D3

F.3 Test Setup

The barrier under test is a single-leaf, reflective plywood traffic noise barrier. Each element is 2.4m wide x 3.9m high, constructed from three and a half 1.2m x 2.4m plywood sheets. The section of barrier under test is situated on the northern side of SH18. Figure F.1 shows the traffic noise barrier viewed from the road-side, the crosses show the approximate positions of the loudspeaker/centre microphone axis.

The measurement points are on the rear-side of the barrier, on a vertical measurement grid of 3 x 3 points with equal horizontal and vertical distances of 0.40m. This measurement grid was located horizontally in the middle of the second plywood sheet (element measurement), two element measurements were performed. The loudspeaker/centre microphone height was 1.9m above the ground.

The barrier thickness at the height of measurement is ~20mm.

The Adrienne temporal window length has been chosen to exclude any parasitic reflections that may otherwise affect the measurement results. Leaks have been included in the calculation as these may significantly influence the airborne sound insulation of the traffic noise barrier.

The loudspeaker and microphone array are shown in Figure F.1 and F.2, respectively.

Figure F.1 Test arrangement showing the loudspeaker when measuring across an element, the crosses mark the measurement positions

Figure F.2 Test arrangement showing the microphone array when measuring across an element

F.4 Test Object

Figure F.3 shows the composition of the plywood traffic noise barrier. Each element of the barrier is constructed from three and a half 1.2m x 2.4m plywood sheets. The joints between adjacent plywood sheets are covered by lengths of 2x4" timber. The entire barrier is supported by large timber posts on the rear-side of the barrier, spaced 2.5m apart.

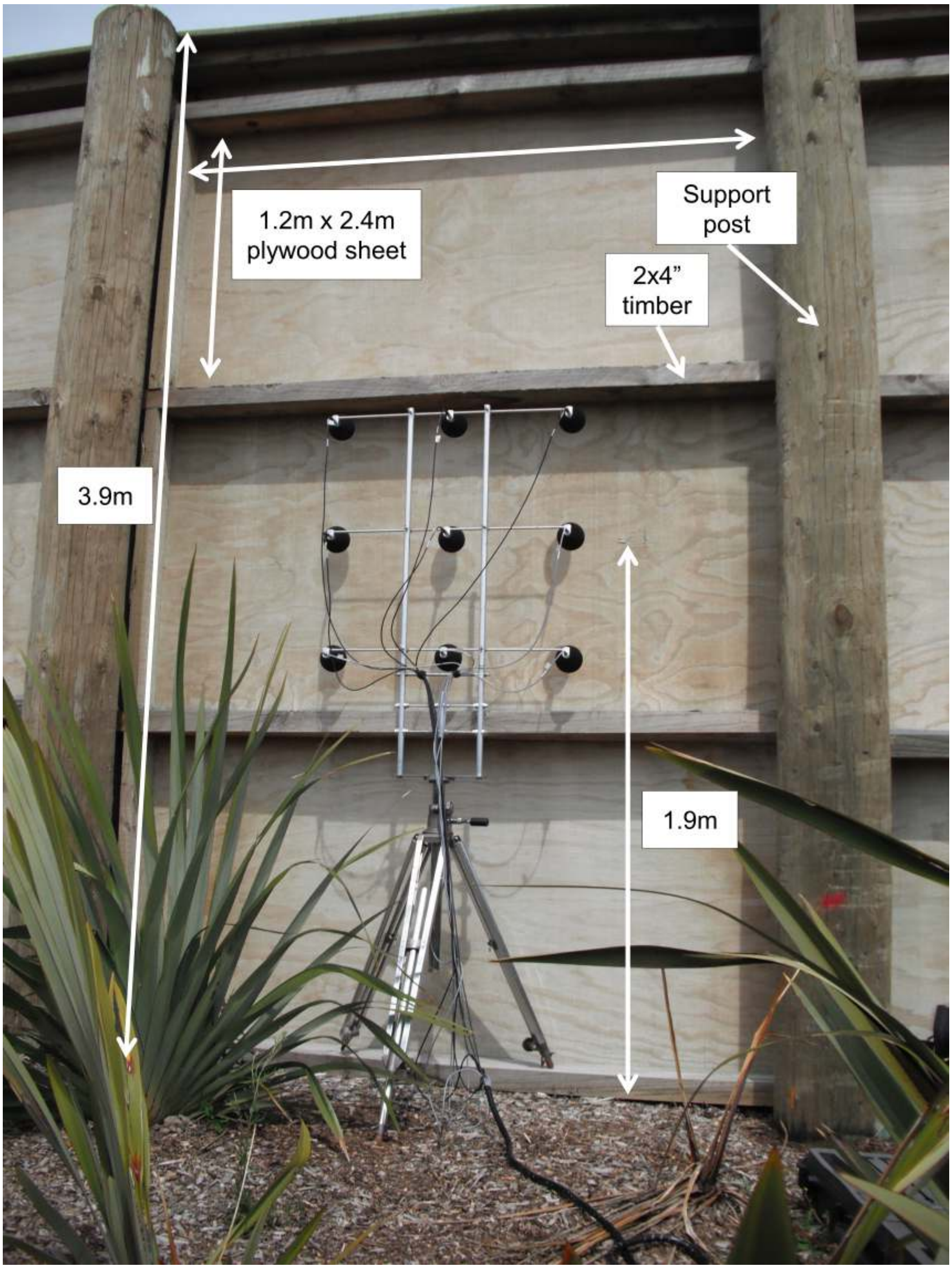

Figure F.3 Composition of the plywood traffic noise barrier, test setup during an element measurement

F.5 Results

F.5.1 Results for Barrier Element 1

Table F.1 Airborne sound insulation values at nine microphone positions and logarithmic average for the element measurement

Microphone Positions	160	200	250	315	400	500	630	800	1k	1.25k	1.6k	2k	2.5k	3.15k	4k	5k
SI_1	19.3	24.4	31.5	23.9	20.9	24.2	30.3	29.6	32.8	37.3	34.6	35.5	36.6	38.2	32.6	34.6
SI_2	27.3	28.8	20.9	20.8	30.3	24.3	28.5	29.6	35.2	38.7	41.0	42.5	41.1	43.6	34.8	37.1
SI_3	22.1	22.1	27.0	26.3	21.5	26.4	34.3	30.9	35.9	36.3	38.5	38.5	34.6	37.8	36.5	36.6
SI_4	20.1	25.2	33.9	23.9	23.4	31.1	30.4	31.2	35.0	36.9	32.2	36.1	36.3	41.0	37.7	35.2
SI_5	31.1	23.7	18.9	20.1	28.2	26.2	30.5	29.7	35.8	36.5	38.5	40.2	41.6	47.3	45.2	37.4
SI_6	20.8	24.0	30.2	26.0	25.2	34.1	32.2	31.5	35.9	38.2	34.3	37.2	39.1	43.1	36.3	38.4
SI_7	21.0	25.5	33.8	23.4	21.6	27.4	32.9	30.9	32.9	35.3	35.3	32.5	36.4	43.5	33.9	38.3
SI_8	28.6	26.0	22.2	23.4	33.1	25.2	30.4	29.0	36.1	39.0	41.8	38.8	35.6	39.9	39.8	40.2
SI_9	21.1	24.5	34.0	24.0	21.7	27.8	33.4	29.3	35.7	36.2	38.6	35.2	33.2	38.9	35.5	36.2
Average	21.6	24.1	24.0	22.6	23.1	26.1	30.6	29.6	34.3	36.5	35.6	36.0	35.9	40.1	35.3	36.3

(*One-third Octave Band Centre Frequency (Hz)*)

Single number rating of the airborne sound insulation across an element, $DL_{SI,E1}$ = 29 dB, with a low frequency limit of 160 Hz.

F.5.2 Results for Barrier Element 2

Table F.2 Airborne sound insulation values at nine microphone positions and logarithmic average for the element measurement

Microphone Positions	160	200	250	315	400	500	630	800	1k	1.25k	1.6k	2k	2.5k	3.15k	4k	5k
SI_1	23.0	24.6	27.1	25.3	24.2	29.8	32.2	31.6	35.9	34.1	33.8	41.9	37.8	41.9	36.3	39.1
SI_2	23.9	24.2	24.8	28.6	28.1	26.6	33.3	31.8	34.1	35.6	38.8	38.9	40.5	43.8	38.3	36.5
SI_3	21.1	24.0	29.5	24.0	22.6	29.7	29.0	32.5	33.7	32.9	34.2	35.8	35.7	42.6	32.2	39.6
SI_4	22.2	24.9	24.1	24.7	31.9	34.0	30.9	30.6	34.5	34.2	38.1	41.3	40.1	45.2	38.3	36.1
SI_5	22.4	21.1	20.7	25.0	34.1	31.7	29.2	30.7	36.5	35.6	34.4	36.7	42.9	45.4	44.7	39.1
SI_6	21.4	25.2	25.2	22.8	26.7	32.3	29.3	29.1	41.4	31.6	35.6	39.6	44.3	42.5	33.2	37.3
SI_7	23.3	26.0	26.3	23.6	25.0	31.1	31.6	34.4	35.4	34.4	35.8	40.8	37.7	40.5	32.0	38.8
SI_8	21.8	20.8	21.2	26.2	26.6	25.2	31.5	32.5	34.3	37.4	29.8	30.5	36.7	36.3	33.4	34.1
SI_9	20.5	23.7	26.8	21.6	21.3	28.6	26.8	30.8	33.5	39.1	30.0	31.5	37.7	35.9	34.0	30.7
Average	21.5	23.0	23.7	23.7	24.7	28.5	29.5	30.8	34.5	34.0	33.0	35.0	38.0	39.7	34.1	35.2

(*One-third Octave Band Centre Frequency (Hz)*)

Single number rating of the airborne sound insulation across an element, $DL_{SI,E2}$ = 29 dB, with a low frequency limit of 160 Hz.

F.5.3 Results for Barrier Global

Table F.3 Airborne sound insulation values at nine microphone positions and logarithmic average for the global measurement

Microphone Positions	*One-third Octave Band Centre Frequency (Hz)* 160	200	250	315	400	500	630	800	1k	1.25k	1.6k	2k	2.5k	3.15k	4k	5k
SI_1	20.8	24.5	28.7	24.5	22.2	26.2	31.2	30.5	34.1	35.4	34.2	37.6	37.1	39.6	34.1	36.3
SI_2	25.2	25.9	22.4	23.2	29.0	25.3	30.3	30.6	34.6	36.9	39.8	40.4	40.8	43.7	36.2	36.8
SI_3	21.6	22.9	28.1	25.0	22.0	27.7	30.9	31.6	34.7	34.3	35.8	36.9	35.2	39.5	33.8	37.9
SI_4	21.0	25.0	26.7	24.3	25.8	32.3	30.6	30.9	34.7	35.4	34.2	38.0	37.8	42.6	38.0	35.6
SI_5	24.9	22.2	19.7	21.9	30.2	28.1	29.8	30.2	36.1	36.0	36.0	38.1	42.2	46.3	44.9	38.2
SI_6	21.1	24.5	27.1	24.1	25.9	33.1	30.5	30.2	37.9	33.7	34.9	38.3	41.0	42.8	34.5	37.9
SI_7	22.0	25.7	28.6	23.5	23.0	28.9	32.2	32.3	34.0	34.8	35.5	34.9	37.0	41.8	32.8	38.5
SI_8	24.0	22.7	21.7	24.6	28.7	25.2	31.0	30.4	35.1	38.1	32.5	32.9	36.1	37.8	35.5	36.1
SI_9	20.8	24.1	29.1	22.6	21.5	28.2	29.0	30.0	34.5	37.4	32.5	33.0	34.9	37.1	34.7	32.6
Average	22.1	24.0	24.4	23.6	24.3	27.6	30.5	30.7	34.9	35.6	34.6	36.0	37.3	40.4	35.2	36.3

Single number rating for the global airborne sound insulation, $DL_{SI,G}$ = 29 dB, with a low frequency limit of 160 Hz.

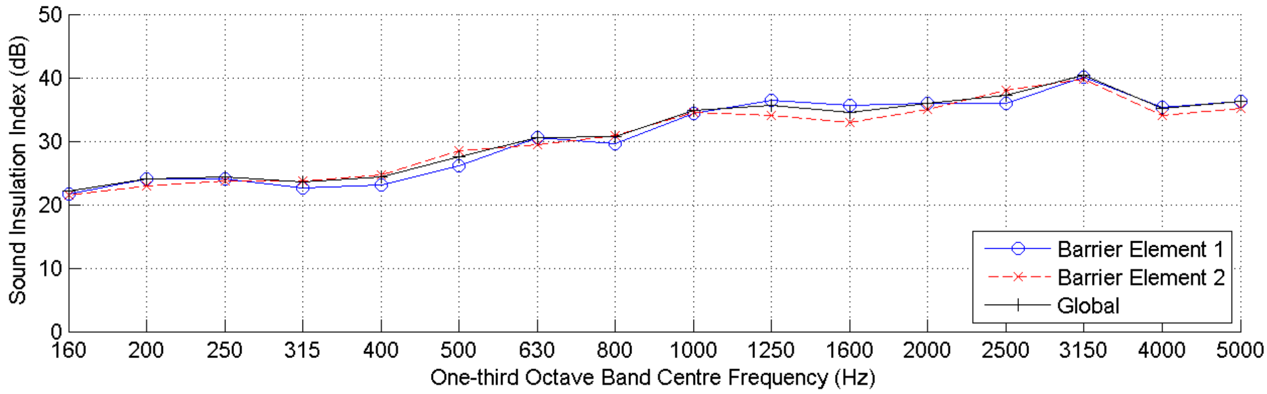

Figure F.4 Airborne sound insulation values, logarithmically averaged over nine microphone positions

Appendix G

Airborne Sound Insulation of the 3.3m Concrete Barrier at Green Lane East

G.1 Introduction

The tests described in this report were conducted on 25 October 2012. The tests were performed at the request of the NZ Transport Agency (NZTA) to determine the airborne sound insulation of the concrete traffic noise barrier at Green Lane East.

The tests were performed in accordance with the draft European standard EN1793-6:2011 *Road traffic noise reducing devices - Test method for determining the acoustic performance - Part 6: Intrinsic characteristics - In situ values of airborne sound insulation under direct sound field conditions*.

G.2 Test Summary

Name and address of testing organisation:
Acoustics Research Group
University of Canterbury
Christchurch 8041
New Zealand

Test Date:
25 October 2012
Test Location:
Green Lane East

Test Setup:
see description and photographic presentation in Section G.3

Test Object:

Manufacturer:	unknown
Type:	concrete
Dimensions:	3.3m high, 2.5m wide, ~120mm thick
Date of installation:	2011
Physical condition during test (visual inspection):	good
Composition:	see description and photographic presentation in Section G.4

Meteorological conditions prevailing during the test:

Wind speed:	0 m/s
Air temperature:	19.4 °C
Air pressure:	100.06 kPa
Relative Humidity:	52.7 %

Test arrangement:
see description and photographic presentation in Section G.3

Equipment used for measurement and analysis:

Sound source

Description:	single driver (12 inch diameter, 600W) sealed loudspeaker, enclosure dimensions: 400mm x 400mm x 450mm

Microphones

Manufacturer:	Bruel & Kjaer
Type:	Type 4189 (1/2" pre-polarised, free-field) Type 2669-C preamplifier (microphones 1-5) Type 2669-L preamplifier (microphones 6-9)
Serial numbers:	2573559 (microphone 1) 2573560 (microphone 2) 2573563 (microphone 3) 2573562 (microphone 4) 2573561 (microphone 5) 2626749 (microphone 6) 2593736 (microphone 7) 2674393 (microphone 8) 2674394 (microphone 9)

Analyser

Manufacturer:	Bruel & Kjaer
Type:	Type 7539 (5 channels)
Serial number:	2472233

Filtering and sampling

Anti-aliasing filter type:	3rd order Butterworth
Sample rate:	65,536 Hz

Adrienne temporal window

Length:	5.5 ms (barrier element) 5.5 ms (barrier post)

Test frequency range

Low frequency limit:	250 Hz (barrier element), 250 Hz (barrier post)
Smallest dimension:	3.3m (barrier height)

Test results

see tables and graphs in Section G.5

Single-number ratings

The single-number ratings for the airborne sound insulation amount to:

$DL_{SI,E}$ = 55 dB (element)	Category: D4
$DL_{SI,P}$ = 55 dB (post)	Category: D4
$DL_{SI,G}$ = 55 dB (global)	Category: D4

G.3 Test Setup

The barrier under test is a single-leaf, reflective concrete traffic noise barrier constructed of single panels. Each element is 2.5m wide x 3.3m high and is self supported. The section of barrier under test is situated on the eastern side of SH1. Figure G.1 shows the traffic noise barrier viewed from the road-side.

Figure G.1 General view of the traffic noise barrier under test (road-side)

The measurement points are on the rear-side of the barrier, on a vertical measurement grid of 3 x 3 points with equal horizontal and vertical distances of 0.40m. This measurement grid was located horizontally in the middle of an element (element measurement) and in front of an element-element join (post measurement). The loudspeaker/centre microphone height was 1.7m below the barrier top.

The barrier thickness at the height of measurement is ~120mm.

The Adrienne temporal window length has been chosen to exclude any parasitic reflections that may otherwise affect the measurement results.

The loudspeaker and microphone array are shown in Figure G.2 and G.3, respectively.

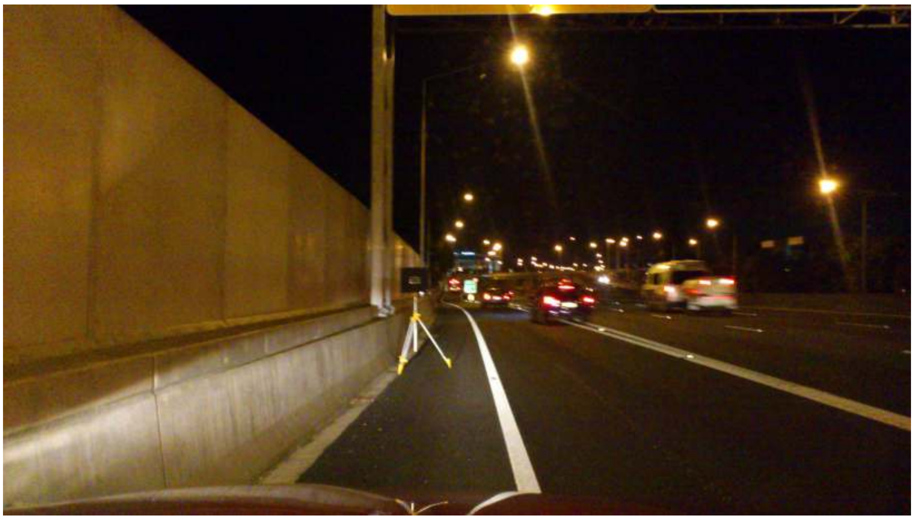

Figure G.2 Test arrangement showing the loudspeaker when measuring across an element

Figure G.3 Test arrangement showing the microphone array when measuring across an element

G.4 Test Object

Figure G.4 shows the composition of the concrete traffic noise barrier. Each element of the barrier is constructed from a 2.5m wide solid concrete slab on top of a 1m high concrete crash barrier. The ground on the rear-side of the barrier is 0.8m lower than the road surface. The gaps between the concrete slabs have been filled with silicon.

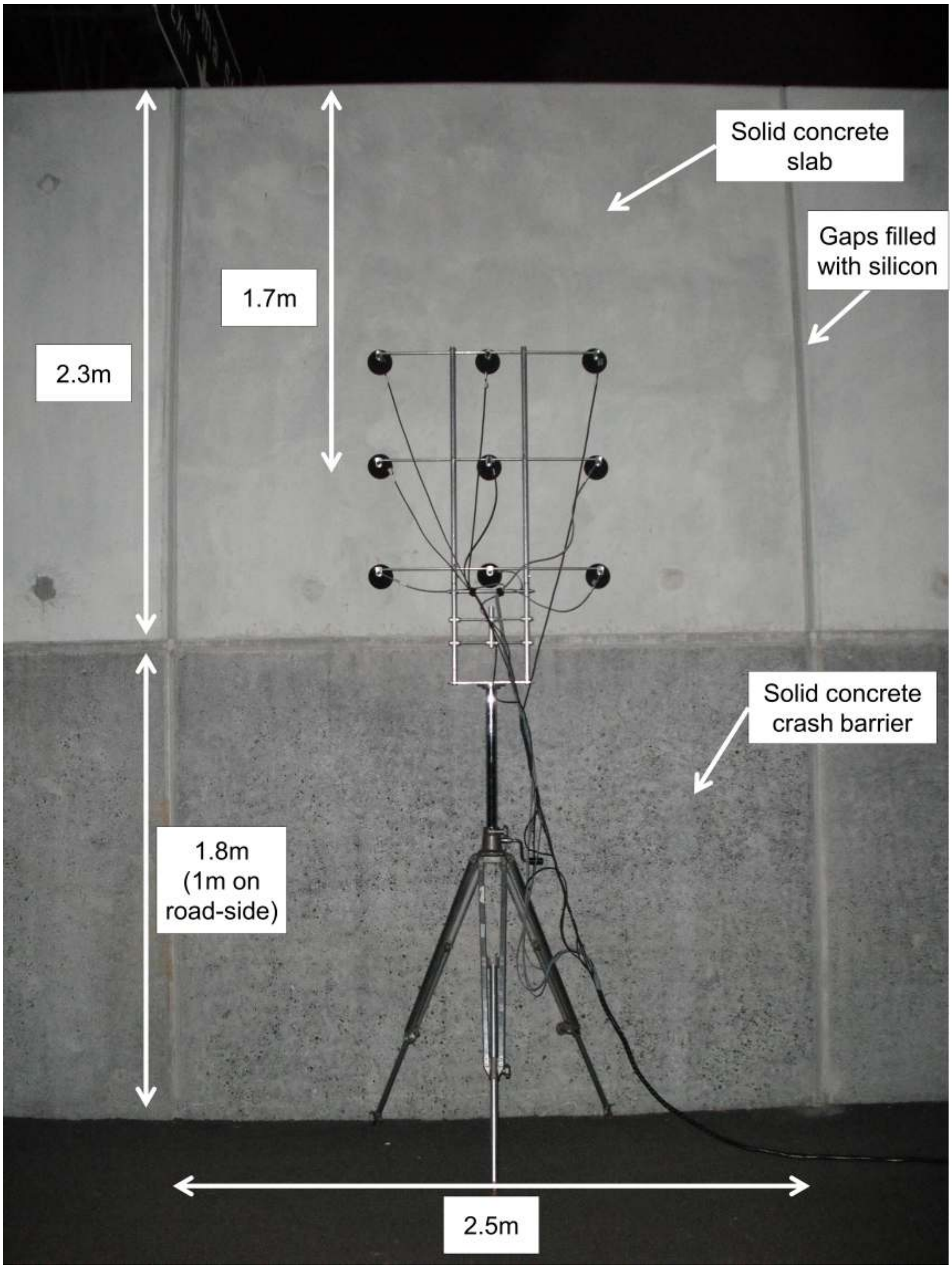

Figure G.4 Composition of the concrete traffic noise barrier, test setup during an element measurement

G.5 Results

G.5.1 Results for Barrier Element

Table G.1 Airborne sound insulation values at nine microphone positions and logarithmic average for the element measurement, highlighted values are below the low frequency limit

Microphone Positions	*One-third Octave Band Centre Frequency (Hz)* 160	200	250	315	400	500	630	800	1k	1.25k	1.6k	2k	2.5k	3.15k	4k	5k
SI_1	44.7	50.1	48.5	45.6	46.0	51.8	58.9	55.0	59.0	62.6	59.0	60.1	62.2	60.5	52.8	48.9
SI_2	43.3	47.4	53.0	49.9	46.4	47.8	56.6	55.6	57.9	64.2	61.2	57.8	61.9	62.4	54.0	53.0
SI_3	32.4	39.3	46.6	46.0	51.5	48.5	49.6	50.5	53.6	55.2	51.6	56.0	53.8	54.0	50.6	48.7
SI_4	35.3	41.7	54.0	53.6	51.8	54.2	60.0	57.1	55.0	58.7	59.3	64.1	67.7	62.6	61.3	60.9
SI_5	41.1	44.8	49.5	56.2	59.4	53.4	52.3	58.4	55.9	62.1	71.7	66.8	64.6	70.3	71.9	64.6
SI_6	43.3	46.9	51.2	56.3	59.1	54.8	50.6	52.3	58.7	62.2	56.9	61.7	63.7	64.4	66.1	64.3
SI_7	43.2	52.5	52.3	49.7	53.8	59.9	56.5	61.5	63.8	63.3	64.0	66.3	73.9	68.4	64.2	66.4
SI_8	45.6	52.0	53.1	52.1	55.2	65.3	72.8	69.7	62.5	63.9	68.6	70.0	72.8	67.5	68.5	73.2
SI_9	45.5	48.3	49.3	50.0	53.4	57.7	55.1	61.2	62.3	67.3	63.8	68.0	71.2	75.6	73.7	71.2
Average	38.3	44.4	49.7	49.1	50.2	51.9	53.5	54.9	57.0	60.2	57.8	60.6	60.9	60.7	56.1	53.8

Single number rating of the airborne sound insulation across an element, $DL_{SI,E}$ = 55 dB, with a low frequency limit of 250 Hz.

G.5.2 Results for Barrier Post

Table G.2 Airborne sound insulation values at nine microphone positions and logarithmic average for the post measurement, highlighted values are below the low frequency limit

Microphone Positions	*One-third Octave Band Centre Frequency (Hz)* 160	200	250	315	400	500	630	800	1k	1.25k	1.6k	2k	2.5k	3.15k	4k	5k
SI_1	33.2	39.6	50.3	53.5	52.9	49.2	51.5	53.6	57.5	59.4	58.7	60.1	65.0	59.1	46.2	49.9
SI_2	43.9	46.3	48.5	48.2	47.2	49.2	57.7	55.0	58.5	59.0	62.3	61.6	64.6	67.6	48.8	52.8
SI_3	31.6	37.0	44.4	53.4	54.4	48.1	50.9	54.5	55.3	57.0	58.0	61.7	64.1	57.3	46.7	49.3
SI_4	46.9	47.5	48.5	50.9	55.9	56.6	56.5	59.9	58.4	66.5	63.1	67.8	69.6	65.7	64.9	64.8
SI_5	42.4	44.7	48.1	52.8	55.3	51.8	51.0	57.6	57.1	61.4	59.9	65.9	76.1	75.6	67.9	65.2
SI_6	38.4	40.7	44.2	50.1	61.0	54.5	50.4	55.3	60.9	63.2	63.5	63.8	68.9	63.3	65.9	62.3
SI_7	39.5	43.2	48.8	56.5	57.7	61.4	62.4	60.3	60.9	62.5	61.9	73.6	74.8	69.2	68.7	71.2
SI_8	39.7	42.4	46.9	54.9	59.2	61.2	68.4	64.2	64.5	59.8	59.5	71.5	72.6	70.8	70.6	68.9
SI_9	41.8	43.7	46.8	52.6	61.2	54.7	56.0	63.8	62.7	66.1	67.8	70.5	72.6	74.3	64.9	66.8
Average	36.7	41.1	46.4	51.4	53.3	51.5	53.1	56.4	58.2	60.2	60.3	63.7	67.4	62.7	51.3	54.4

Single number rating of the airborne sound insulation across a post, $DL_{SI,P}$ = 55 dB, with a low frequency limit of 250 Hz.

G.5.3 Results for Barrier Global

Table G.3 Airborne sound insulation values at nine microphone positions and logarithmic average for the global measurement, highlighted values are below the low frequency limit

Microphone Positions	160	200	250	315	400	500	630	800	1k	1.25k	1.6k	2k	2.5k	3.15k	4k	5k
SI_1	36.0	42.3	49.3	48.0	48.2	50.3	53.8	54.2	58.2	60.7	58.8	60.1	63.4	59.7	48.4	49.3
SI_2	43.6	46.8	50.2	49.0	46.8	48.4	57.1	55.3	58.2	60.9	61.7	59.3	63.1	64.3	50.7	52.9
SI_3	32.0	38.0	45.4	48.3	52.7	48.3	50.2	52.1	54.4	56.0	53.7	58.0	56.4	55.4	48.3	49.0
SI_4	38.0	43.7	50.4	52.1	53.4	55.2	57.9	58.3	56.4	61.0	60.8	65.6	68.5	63.9	62.7	62.4
SI_5	41.7	44.7	48.7	54.2	56.9	52.5	51.6	58.0	56.4	61.7	62.6	66.3	67.3	72.2	69.4	64.9
SI_6	40.2	42.8	46.4	52.2	60.0	54.6	50.5	53.5	59.7	62.7	59.0	62.6	65.6	63.8	66.0	63.2
SI_7	40.9	45.7	50.2	51.9	55.3	60.6	58.6	60.8	62.1	62.9	62.8	68.6	74.4	68.8	65.9	68.2
SI_8	41.7	44.9	49.0	53.3	56.8	62.8	70.1	66.2	63.4	61.4	62.0	70.7	72.7	68.8	69.4	70.5
SI_9	43.3	45.4	47.9	51.1	55.8	55.9	55.5	62.3	62.5	66.7	65.4	69.1	71.9	74.9	67.4	68.4
Average	37.9	43.0	48.3	50.6	52.0	52.2	53.8	56.1	58.1	60.7	59.4	62.4	63.5	62.1	53.6	54.6

(Column headers grouped under: *One-third Octave Band Centre Frequency (Hz)*)

Single number rating for the global airborne sound insulation, $DL_{SI,G}$ = 55 dB, with a low frequency limit of 250 Hz.

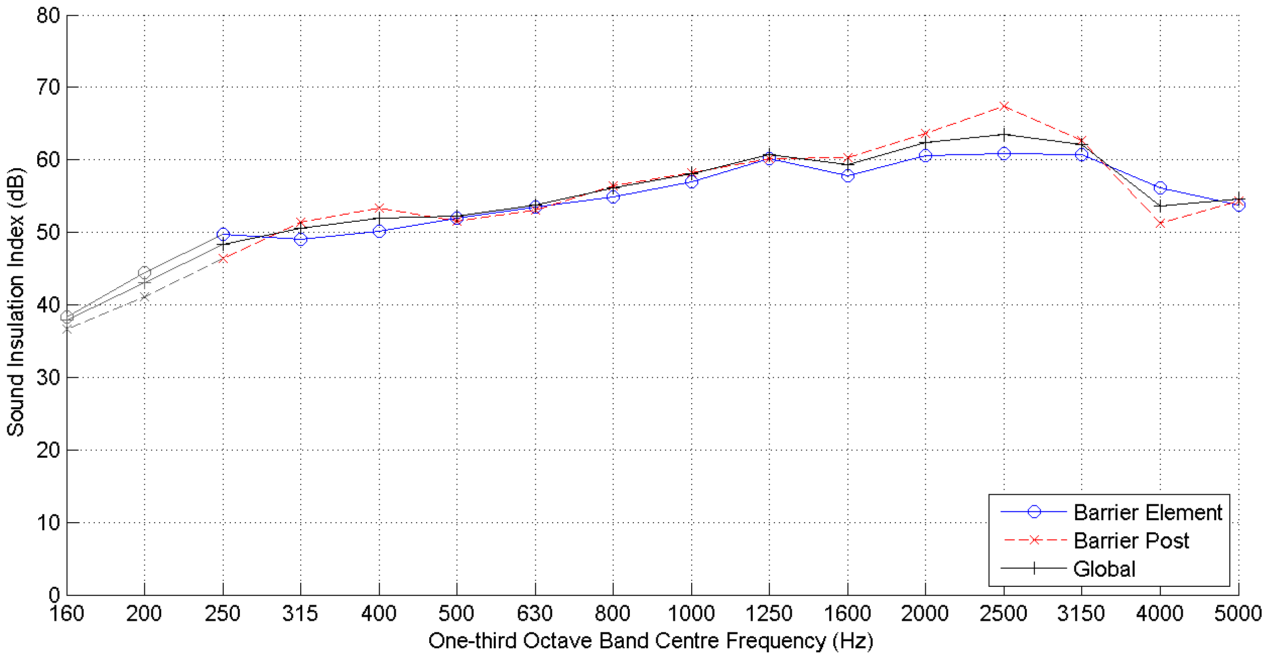

Figure G.5 Airborne sound insulation values, logarithmically averaged over nine microphone positions. The grey lines represent values below the low frequency limit of the measurement.

Appendix H

Airborne Sound Insulation of the 3.9m Timber Barrier at Kingsland Cycleway

H.1 Introduction

The tests described in this report were conducted on 26 October 2012. The tests were performed at the request of the NZ Transport Agency (NZTA) to determine the airborne sound insulation of the timber plank barrier at Kingsland Cycleway.

The tests were performed in accordance with the draft European standard EN1793-6:2011 *Road traffic noise reducing devices - Test method for determining the acoustic performance - Part 6: Intrinsic characteristics - In situ values of airborne sound insulation under direct sound field conditions*.

H.2 Test Summary

Name and address of testing organisation:
Acoustics Research Group
University of Canterbury
Christchurch 8041
New Zealand

Test Date:
26 October 2012
Test Location:
Kingsland Cycleway

Test Setup:
see description and photographic presentation in Section H.3

Test Object:

Manufacturer:	unknown
Type:	timber plank
Dimensions:	3.9m high, 2m wide, ~20mm thick planks
Date of installation:	2010
Physical condition during test (visual inspection):	warped planks
Composition:	see description and photographic presentation in Section H.4

Meteorological conditions prevailing during the test:

Wind speed:	1.5 m/s
Air temperature:	20.5 °C
Air pressure:	100.6 kPa
Relative Humidity:	48.3 %

Test arrangement:
see description and photographic presentation in Section H.3

Equipment used for measurement and analysis:

Sound source

Description:	single driver (12 inch diameter, 600W) sealed loudspeaker, enclosure dimensions: 400mm x 400mm x 450mm

Microphones

Manufacturer:	Bruel & Kjaer
Type:	Type 4189 (1/2" pre-polarised, free-field) Type 2669-C preamplifier (microphones 1-5) Type 2669-L preamplifier (microphones 6-9)
Serial numbers:	2573559 (microphone 1) 2573560 (microphone 2) 2573563 (microphone 3) 2573562 (microphone 4) 2573561 (microphone 5) 2626749 (microphone 6) 2593736 (microphone 7) 2674393 (microphone 8) 2674394 (microphone 9)

Analyser

Manufacturer:	Bruel & Kjaer
Type:	Type 7539 (5 channels)
Serial number:	2472233

Filtering and sampling

Anti-aliasing filter type:	3rd order Butterworth
Sample rate:	65,536 Hz

Adrienne temporal window

Length:	6.5 ms (barrier element 1) 6.5 ms (barrier element 2)

Test frequency range

Low frequency limit:	250 Hz (barrier element 1), 250 Hz (barrier element 2)
Smallest dimension:	3.9m (barrier height)

Test results

see tables and graphs in Section H.5

Single-number ratings

The single-number ratings for the airborne sound insulation amount to:

$DL_{SI,E1}$ = 19 dB (element)	Category: D2
$DL_{SI,E2}$ = 19 dB (element)	Category: D2
$DL_{SI,G}$ = 19 dB (global)	Category: D2

H.3 Test Setup

The barrier under test is a single-leaf, reflective timber plank traffic noise barrier. Each element is 2m wide x 3.9m high, constructed from overlapped vertical timber planks. The section of barrier under test is situated on the southern side of SH16. Figure H.1 shows the traffic noise barrier viewed from the road-side, the crosses show the approximate positions of the loudspeaker/centre microphone axis.

The measurement points are on the rear-side of the barrier, on a vertical measurement grid of 3 x 3 points with equal horizontal and vertical distances of 0.40m. This measurement grid was located vertically between the horizontal timber supports (element measurement), two element measurements were performed. The loudspeaker/centre microphone height was 2.1m above the ground.

The barrier thickness at the height of measurement is ~20mm.

The Adrienne temporal window length has been chosen to exclude any parasitic reflections that may otherwise affect the measurement results. Leaks have been included in the calculation as these may significantly influence the airborne sound insulation of the traffic noise barrier.

The loudspeaker and microphone array are shown in Figure H.1 and H.2, respectively.

Figure H.1 Test arrangement showing the loudspeaker when measuring across an element, the crosses mark the measurement positions

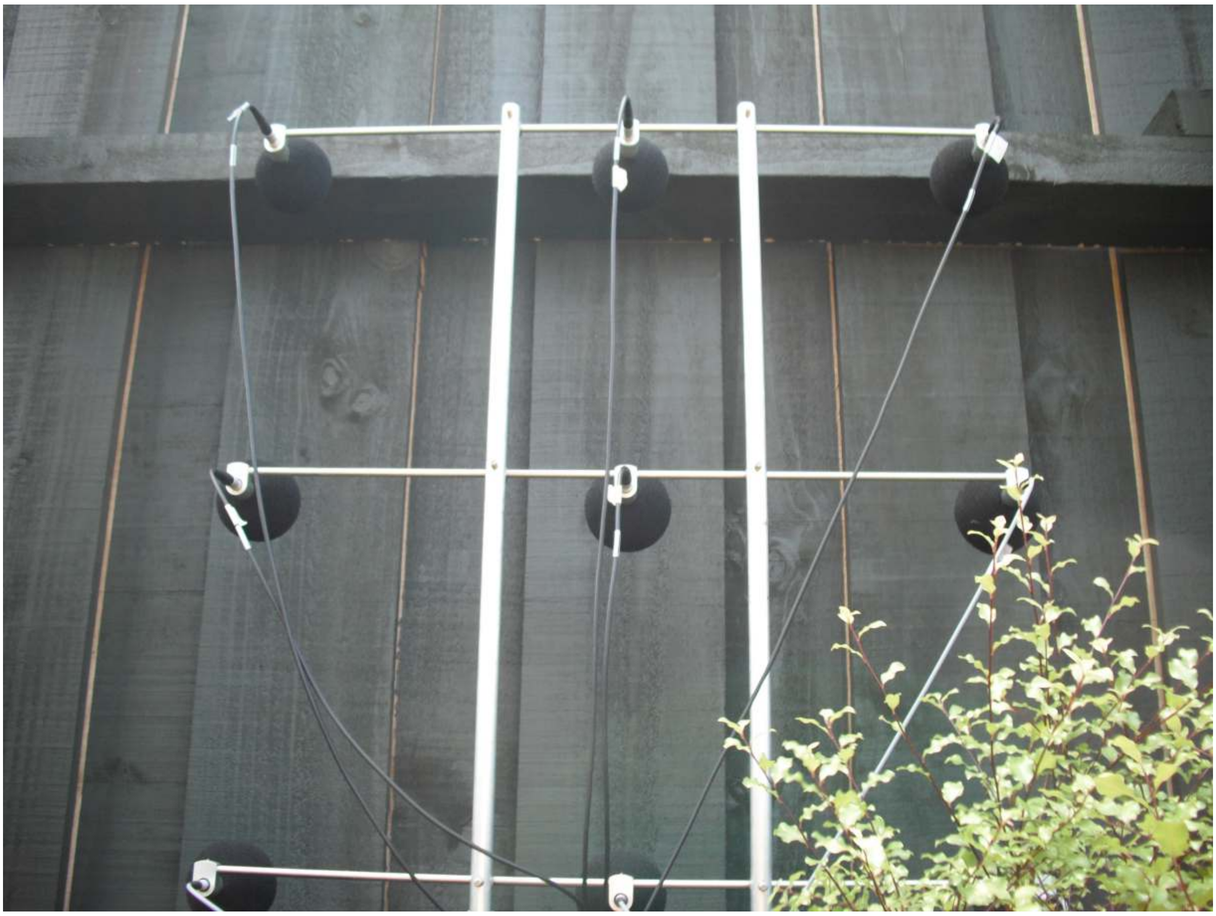

Figure H.2 Test arrangement showing the microphone array when measuring across an element

H.4 Test Object

Figure H.3 shows the composition of the timber plank traffic noise barrier. Each element of the barrier is constructed from overlapped vertical timber planks and supported on the rear-side by horizontal lengths of 2x4" timber. The entire barrier is supported by large timber posts on the rear-side of the barrier, spaced approximately 2m apart.

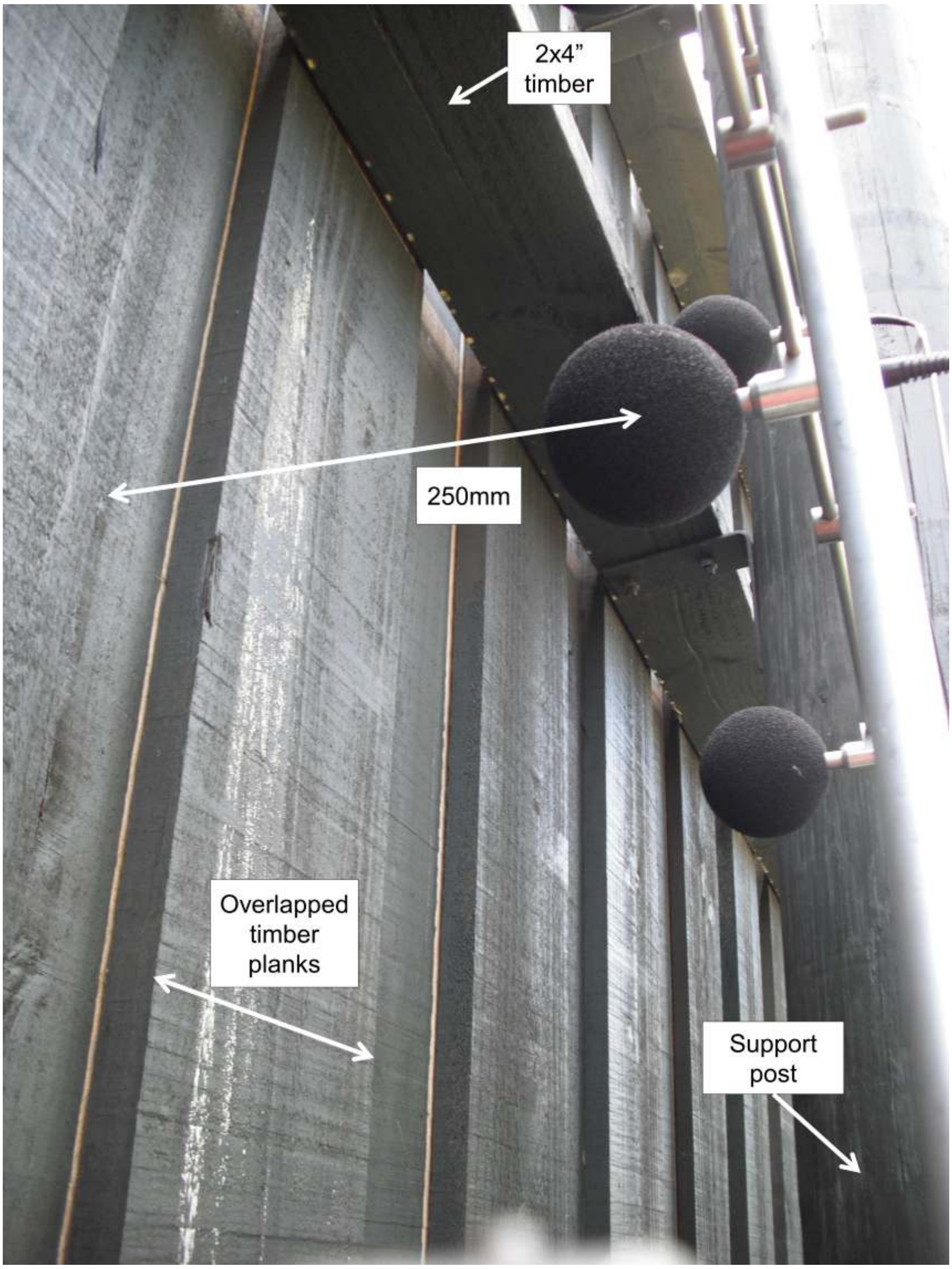

Figure H.3 Composition of the timber plank traffic noise barrier

H.5 Results

H.5.1 Results for Barrier Element 1

Table H.1 Airborne sound insulation values at nine microphone positions and logarithmic average for the element measurement, highlighted values are below the low frequency limit

Microphone Positions	*One-third Octave Band Centre Frequency (Hz)* 160	200	250	315	400	500	630	800	1k	1.25k	1.6k	2k	2.5k	3.15k	4k	5k
SI_1	13.1	15.4	18.7	24.6	24.4	20.1	20.1	27.8	27.3	26.7	24.1	23.9	14.1	12.3	15.7	19.5
SI_2	17.5	19.1	21.6	24.6	22.5	20.4	24.8	24.3	21.1	29.4	19.1	19.1	13.8	12.9	21.6	22.6
SI_3	15.1	16.2	18.5	23.9	23.6	20.9	23.0	26.0	25.8	24.1	22.1	15.2	10.0	14.5	14.9	20.0
SI_4	14.1	16.2	17.9	17.7	18.6	24.4	24.9	23.6	25.2	26.8	23.7	23.8	16.2	11.4	15.9	21.1
SI_5	16.9	19.0	18.9	17.4	19.2	27.3	28.8	22.3	20.5	24.9	17.2	18.7	16.8	18.3	23.1	22.6
SI_6	15.0	16.8	18.8	19.5	20.3	25.3	35.5	24.8	26.0	27.9	26.0	18.7	14.2	17.8	17.5	19.4
SI_7	13.6	15.1	17.5	20.3	19.1	17.3	17.4	21.7	23.5	25.2	27.6	21.7	13.4	9.9	13.5	21.0
SI_8	17.3	18.3	18.4	19.0	22.0	20.7	20.0	24.3	19.0	25.9	15.4	17.1	11.2	15.1	17.7	16.6
SI_9	15.8	16.4	18.0	22.3	25.6	22.0	20.6	24.8	31.4	25.2	23.6	18.1	10.2	14.2	18.2	17.7
Average	14.6	16.2	18.1	19.7	20.6	20.7	21.3	23.6	22.6	25.5	19.8	18.3	12.2	12.8	16.2	19.1

Single number rating of the airborne sound insulation across an element, $DL_{SI,E1}$ = 19 dB, with a low frequency limit of 250 Hz.

H.5.2 Results for Barrier Element 2

Table H.2 Airborne sound insulation values at nine microphone positions and logarithmic average for the element measurement, highlighted values are below the low frequency limit

Microphone Positions	*One-third Octave Band Centre Frequency (Hz)* 160	200	250	315	400	500	630	800	1k	1.25k	1.6k	2k	2.5k	3.15k	4k	5k
SI_1	18.4	18.1	18.6	21.9	23.9	20.4	23.5	22.9	23.5	23.6	20.6	20.0	15.5	16.2	15.6	24.7
SI_2	17.7	19.5	20.3	20.8	22.5	19.0	16.4	22.9	28.4	27.2	23.8	18.1	10.2	16.4	17.1	24.8
SI_3	15.7	17.1	19.9	27.1	24.4	20.0	21.5	21.6	24.8	22.2	20.8	19.8	11.7	9.6	16.9	25.0
SI_4	16.0	18.7	19.5	17.4	17.6	22.6	29.6	23.5	21.9	23.5	23.3	22.3	20.9	19.0	17.6	23.4
SI_5	17.1	18.7	18.4	17.4	19.2	24.3	26.8	23.4	25.0	25.3	22.3	18.9	14.2	21.4	26.4	25.5
SI_6	15.6	17.0	19.0	21.6	23.4	27.9	26.0	22.5	23.6	21.8	22.0	20.0	12.2	16.6	18.1	21.9
SI_7	16.0	17.8	20.8	22.7	18.9	17.9	20.2	18.2	20.9	20.9	18.8	18.8	10.8	14.0	16.1	22.5
SI_8	17.6	18.1	18.5	20.1	23.5	19.4	16.9	23.3	28.3	22.9	25.5	16.7	9.9	16.0	18.3	25.4
SI_9	15.1	15.5	16.9	21.1	29.0	24.7	24.1	27.4	26.7	22.3	22.1	19.7	12.0	11.2	14.5	17.3
Average	15.9	17.2	18.5	19.8	20.8	20.4	20.3	21.7	23.6	22.5	21.2	18.6	11.7	13.7	16.5	22.0

Single number rating of the airborne sound insulation across an element, $DL_{SI,E2}$ = 19 dB, with a low frequency limit of 250 Hz.

H.5.3 Results for Barrier Global

Table H.3 Airborne sound insulation values at nine microphone positions and logarithmic average for the global measurement, highlighted values are below the low frequency limit

Microphone	*One-third Octave Band Centre Frequency (Hz)*															
Positions	160	200	250	315	400	500	630	800	1k	1.25k	1.6k	2k	2.5k	3.15k	4k	5k
SI_1	15.0	16.5	18.7	23.0	24.1	20.2	21.5	24.7	25.0	24.9	22.0	21.5	14.8	13.9	15.7	21.4
SI_2	17.6	19.3	20.9	22.3	22.5	19.7	18.8	23.6	23.4	28.2	20.8	18.5	11.7	14.3	18.8	23.5
SI_3	15.4	16.6	19.1	25.2	24.0	20.4	22.2	23.2	25.3	23.1	21.4	16.9	10.8	11.4	15.8	21.8
SI_4	14.9	17.3	18.7	17.5	18.1	23.4	26.7	23.5	23.2	24.8	23.5	23.0	17.9	13.7	16.7	22.1
SI_5	17.0	18.8	18.7	17.4	19.2	25.5	27.7	22.8	22.2	25.1	19.1	18.8	15.3	19.6	24.4	23.8
SI_6	15.3	16.9	18.9	20.4	21.6	26.4	28.5	23.5	24.6	23.9	23.5	19.3	13.1	17.1	17.8	20.5
SI_7	14.6	16.2	18.8	21.4	19.0	17.6	18.6	19.6	22.0	22.5	21.3	20.0	11.9	11.5	14.6	21.7
SI_8	17.4	18.2	18.5	19.5	22.7	20.0	18.2	23.8	21.6	24.2	18.0	16.9	10.5	15.5	18.0	19.1
SI_9	15.5	15.9	17.4	21.7	27.0	23.2	22.0	25.9	28.5	23.5	22.8	18.8	11.0	12.4	16.0	17.5
Average	15.7	17.2	18.8	20.3	21.2	21.0	21.3	23.1	23.6	24.2	21.0	18.9	12.4	13.8	16.9	20.8

Single number rating for the global airborne sound insulation, $DL_{SI,G}$ = 19 dB, with a low frequency limit of 250 Hz.

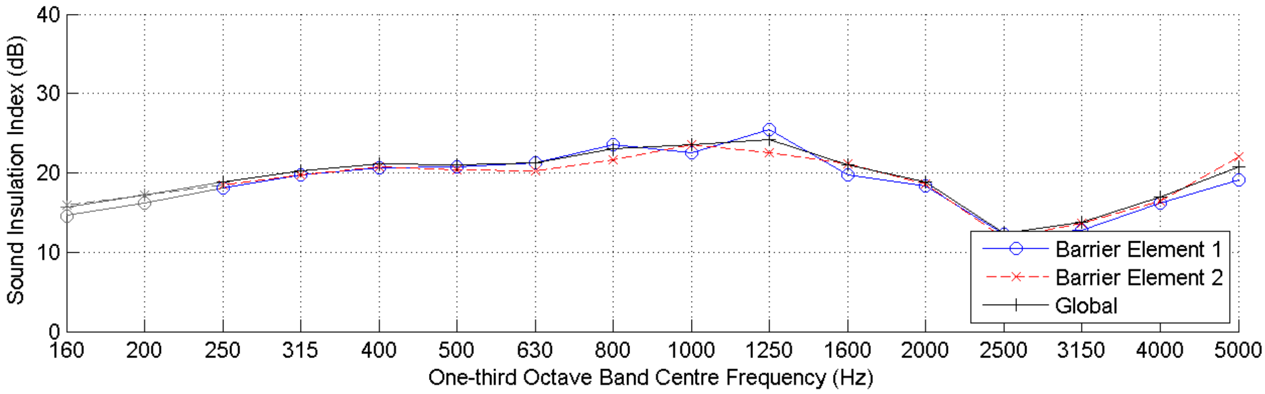

Figure H.4 Airborne sound insulation values, logarithmically averaged over nine microphone positions. The grey lines represent values below the low frequency limit of the measurement.

Appendix I

Airborne Sound Insulation of the 2.1m Plywood Barrier at Northern Busway

I.1 Introduction

The tests described in this report were conducted on 24 October 2012. The tests were performed at the request of the NZ Transport Agency (NZTA) to determine the airborne sound insulation of the plywood barrier at Northern Busway.

The tests were performed in accordance with the draft European standard EN1793-6:2011 *Road traffic noise reducing devices - Test method for determining the acoustic performance - Part 6: Intrinsic characteristics - In situ values of airborne sound insulation under direct sound field conditions*.

I.2 Test Summary

Name and address of testing organisation:

Acoustics Research Group
University of Canterbury
Christchurch 8041
New Zealand

Test Date:

24 October 2012

Test Location:

Northern Busway

Test Setup:

see description and photographic presentation in Section I.3

Test Object:

Manufacturer:	unknown
Type:	plywood
Dimensions:	2.1m high, 1.2m wide, ~20mm thick
Date of installation:	2008

Physical condition during test (visual inspection): gaps at base

Composition:	see description and photographic presentation in Section I.4

Meteorological conditions prevailing during the test:

Wind speed:	1.2 m/s
Air temperature:	19.5 °C
Air pressure:	101.80 kPa
Relative Humidity:	43.3 %

Test arrangement:

see description and photographic presentation in Section I.3

Equipment used for measurement and analysis:

Sound source

Description:	single driver (6 inch diameter, 80W) sealed loudspeaker, enclosure dimensions: 300mm x 300mm x 300mm

Microphones

Manufacturer:	Bruel & Kjaer
Type:	Type 4189 (1/2" pre-polarised, free-field) Type 2669-C preamplifier (microphones 1-5) Type 2669-L preamplifier (microphones 6-9)
Serial numbers:	2573559 (microphone 1) 2573560 (microphone 2) 2573563 (microphone 3) 2573562 (microphone 4) 2573561 (microphone 5) 2626749 (microphone 6) 2593736 (microphone 7) 2674393 (microphone 8) 2674394 (microphone 9)

Analyser

Manufacturer:	Bruel & Kjaer
Type:	Type 7539 (5 channels)
Serial number:	2472233

Filtering and sampling

Anti-aliasing filter type:	3rd order Butterworth
Sample rate:	65,536 Hz

Adrienne temporal window

Length:	3.5 ms (barrier element)

Test frequency range

Low frequency limit:	400 Hz (barrier element)
Smallest dimension:	2.1m (barrier height)

Test results

see tables and graphs in Section I.5

Single-number ratings

The single-number ratings for the airborne sound insulation amount to:

$DL_{SI,E}$ = 34 dB (element) Category: D3

I.3 Test Setup

The barrier under test is a single-leaf, reflective plywood traffic noise barrier. Each element is 1.2m wide x 2.1m high, constructed from plywood sheets. The section of barrier under test is situated on the eastern side of SH1. Figure I.1 shows the traffic noise barrier viewed from the rear-side, the cross shows the approximate position of the loudspeaker/centre microphone axis.

The measurement points are on the rear-side of the barrier, on a vertical measurement grid of 3 x 3 points with equal horizontal and vertical distances of 0.40m. This measurement grid was located vertically in line with the horizontal timber support (element measurement), only one element measurement was performed. The loudspeaker/centre microphone height was 1.2m above the ground.

The barrier thickness at the height of measurement is ~20mm.

The Adrienne temporal window length has been chosen to exclude any parasitic reflections that may otherwise affect the measurement results.

The loudspeaker and microphone array are shown in Figure I.2 and I.3, respectively.

Figure I.1 Test arrangement showing the microphone array when measuring across an element, the cross marks the measurement position

Figure I.2 Test arrangement showing the loudspeaker when measuring across an element

I.4 Test Object

Figure I.3 shows the composition of the plywood traffic noise barrier. Each element of the barrier is constructed from plywood sheets and supported on the rear-side by lengths of 2x4" timber.

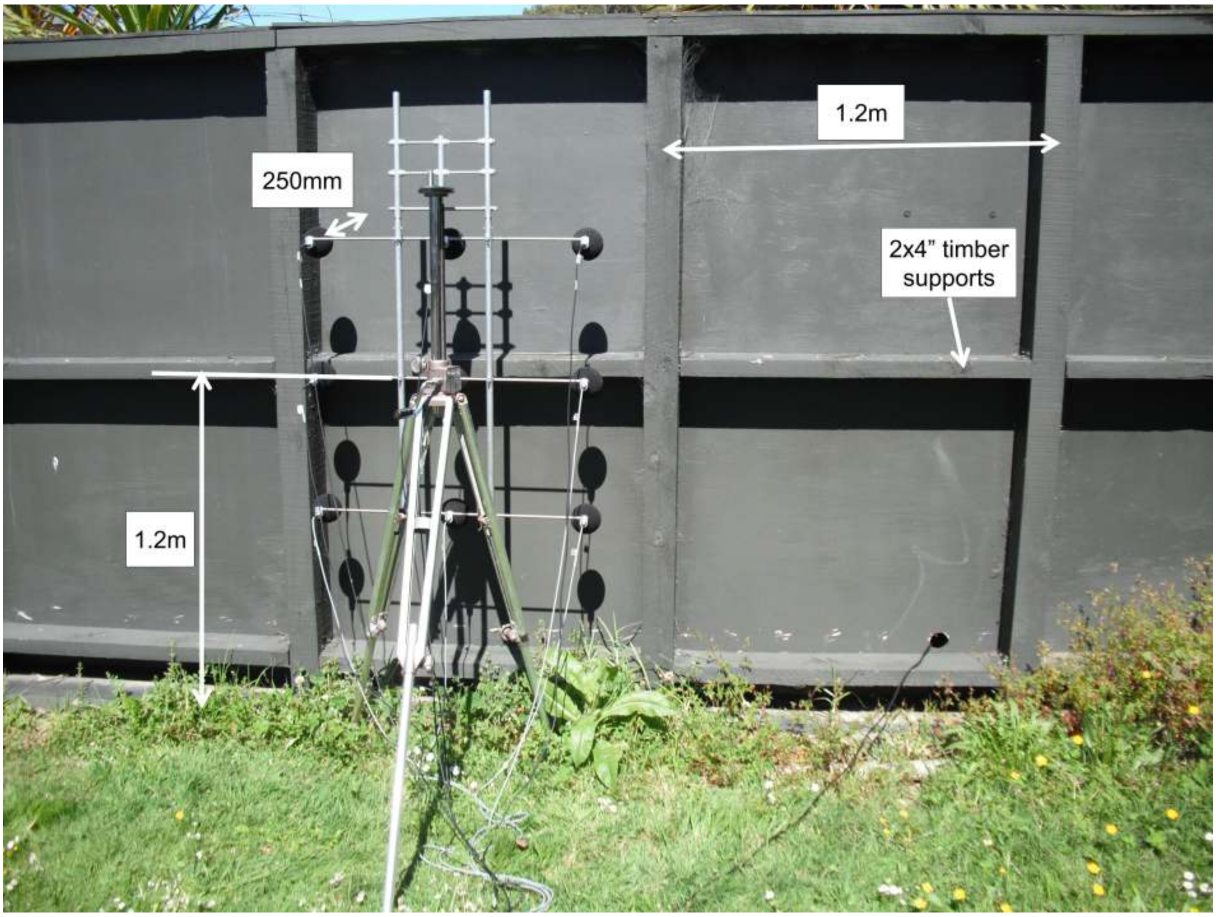

Figure I.3 Composition of the plywood traffic noise barrier

I.5 Results

I.5.1 Results for Barrier Element

Table I.1 Airborne sound insulation values at nine microphone positions and logarithmic average for the element measurement, highlighted values are below the low frequency limit

Microphone	*One-third Octave Band Centre Frequency (Hz)*															
Positions	160	200	250	315	400	500	630	800	1k	1.25k	1.6k	2k	2.5k	3.15k	4k	5k
SI_1	30.7	30.6	30.4	30.3	30.4	31.2	33.1	35.2	35.6	36.5	43.6	35.5	36.7	43.4	47.9	39.6
SI_2	22.9	24.6	26.3	27.8	29.3	31.1	34.0	39.3	42.9	39.7	40.1	39.6	42.9	55.9	51.1	47.9
SI_3	25.4	27.1	28.5	29.5	30.1	30.8	32.6	35.0	35.6	33.3	34.4	42.2	42.0	40.3	45.9	39.6
SI_4	30.5	31.8	32.5	32.6	32.1	31.9	32.9	35.5	41.9	50.1	41.8	41.5	49.7	52.0	43.9	50.4
SI_5	23.0	24.8	26.8	28.9	31.5	35.5	41.9	48.2	50.3	45.5	44.7	41.4	43.5	55.6	49.6	55.2
SI_6	26.3	27.1	28.2	29.8	32.6	38.1	46.5	42.9	39.2	39.6	41.4	44.5	39.8	41.5	51.2	54.7
SI_7	23.5	24.0	24.6	25.3	26.5	28.8	32.5	34.3	35.5	40.3	33.0	28.0	31.1	35.7	43.0	42.8
SI_8	20.9	21.1	21.5	22.2	23.6	26.6	32.0	38.3	42.1	39.8	37.9	33.3	33.5	40.6	41.4	50.3
SI_9	24.4	24.6	24.9	25.4	26.3	27.9	29.8	32.0	36.1	32.9	34.8	36.5	38.4	35.0	42.7	42.9
Average	23.8	24.7	25.5	26.4	27.6	29.7	32.7	35.5	37.6	36.8	36.8	34.4	36.3	39.5	44.5	43.4

Single number rating of the airborne sound insulation across an element, $DL_{SI,E}$ = 34 dB, with a low frequency limit of 400 Hz.

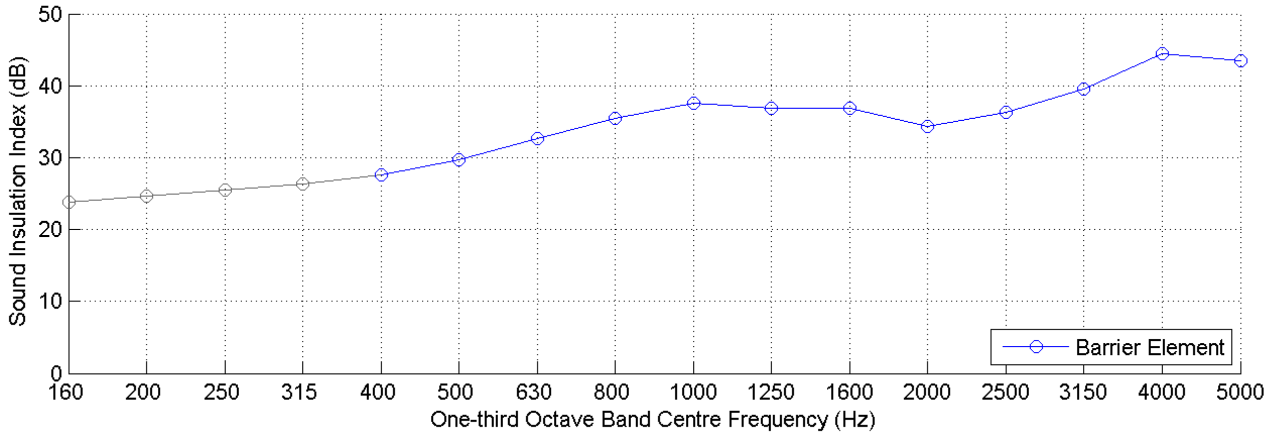

Figure I.4 Airborne sound insulation values, logarithmically averaged over nine microphone positions. The grey lines represent values below the low frequency limit of the measurement.

Appendix J

Motorway Inspections Traffic Management Plan - 18261

NZ TRANSPORT AGENCY
WAKA KOTAHI

Auckland Motorways

MOTORWAY INSPECTIONS TRAFFIC MANAGEMENT PLAN - 18261

Organizations / TMP reference	**TMP reference:** AMA Generic Inspections TMP - 18261	**Contractor:** Auckland Motorway Alliance - MA2884	**Principal** (Client): NZTA Transport Agency **RCA:** NZTA Transport Agency / Auckland Motorway Alliance		
Location details and road characteristics	**Road names and suburb** State Highways: 1, 1K, 16, 18, 18A, 18B, 20, 20A, 20B, 20C, 22		**House No./ RPs** Start to End	**Road level** L1/L2 & L3	**Perm. speed** 50-100km/h
Traffic details	**AADT – Refer to Highway Information Sheets**		**Peak flows: 06h00-09h00 & 15h00-19h00**		
Work Programme	**Start: 02 July 2012**		**End: 30 June 2013**		
Description of work activity	***Note: For the following inspection activities you must be either a STMS L2/3 NP, or a qualified AMA Inspector.** *All inspection activities to be undertaken outside of peak traffic flows whenever possible. *Vehicles accessing sites from the State Highway shall have a rotating amber beacon and these must be used when entering/exiting the State Highway and when parked off the carriageway. *Areas should be inspected prior to the works to ensure that these areas can be accessed safely. *Vehicles should be parked at least 5 meters from the live traffic lanes. If this is not possible then a clear distance of at least 2 meters from the live traffic lanes with good clear site distance, both front and rear may be used for no longer than 30 minutes. *Where sections of the state highway force personnel to be within 2 meters of the live lane, then a spotter must be used, and the inspection may not exceed 5 minutes. *No night time operations on Friday and/or Saturday nights as well as any nights before, during and after a long weekend and/or Public Holiday unless required and approved by the TMC. *No day time operations on Saturdays, Sundays, Long Weekends and/or public holidays unless required and approved by the TMC. *Mobile inspections are not to be undertaken at less than 80kph in a 100kph zone, or more than 20kph slower than the operating speed. ****Note: Where sections of State Highway or motorway are deemed unsafe and/or the operation does not fall within the situations described above, then a site specific TMP must be submitted.**				
Positive Traffic Management Measures	Rotating amber beacon and hazard lights must remain on while inspection is being undertaken and vehicle is stationary. If more than 5 meters from the live lane then switch beacon and hazard lights off. The work activity sign "ROAD INSPECTION" is to be mounted on the rear of the vehicle to indicate the purpose of your presence.				
Contingency Plans:	Traffic volumes, traffic behavior, road and environmental conditions are to be monitored at all times. Work will be abandoned and staff will leave the area immediately if the site has become unsafe. In the case of an accident on site, the site will be made safe and personnel and vehicles will remain as they were at the time of the accident. Traffic will be managed around the site until such time as emergency services arrive.				
Notification	You must advise JTOC (09) 927 9753 before commencing inspections operations.				
Special safety measures	All personnel are to comply with the company health and safety policies. High Visibility (fluorescent orange) vests conforming to the requirements spelt out in Section B3 of COPTTM, lace up steel cap safety footwear, and hard hats must be worn.				

TMP preparation

Prepared	Jim Bernhard		STMS L2/3 NP	480	02 July 2012
	Name (STMS qualified)	*Signature*	*Qualification*	*ID Number*	*Date*

Engineer/TMC to complete following section when approval or acceptance required

Approved by TMC:	Doris Stroh		STMS L2/3 NP	33704	02 July 2012
	Name	*Signature*	*Qualification*	*ID Number*	*Date*

Qualifier for engineer or TMC approval

This TMP is approved on the following basis:

1. To the best of the approving engineer's/TMC's judgment this TMP conforms to the requirements of the NZTA CoPTTM.
2. This plan is approved on the basis that the *activity, the location and the road environment have been correctly represented by the applicant.* Any inaccuracy in the portrayal of this information is the responsibility of the applicant.
3. The STMS for the activity is reminded that it is the STMS's duty to "postpone, cancel or modify operations due to the adverse traffic, weather or other conditions that affect the safety of this site.

NZ TRANSPORT AGENCY
WAKA KOTAHI

Auckland Motorways

MOTORWAY INSPECTIONS TRAFFIC MANAGEMENT PLAN - 18261