150 HOLBORN

NOISE, VIBRATION AND VENTILATION ASSESSMENTS

DAR REAL ESTATES SARL

APRIL 2016

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Consultants in Acoustics, Noise & Vibration

15374-R03-C

7 March 2016

150 Holborn

Planning noise and vibration report

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B	7 Mar 16		Philip Owen BSc, MIOA	Stephen Stringer MSc, BEng, MIOA, MCIBSE, CEng

Summary

This planning noise and vibration report has been prepared by Sandy Brown Associates LLP (SBA) in support of a planning application for the redevelopment of 150 Holborn which is bound by Holborn to the south, Gray's Inn Road to the west and Brooke Street to the east.

The redevelopment will provide a mix of office accommodation (Class B1), retail floorspace (Class A1-A3), residential units (Class C3) and public realm improvements. The description of development is:

> *"Demolition of existing building and redevelopment for a mixed use development up to 9 storeys in height comprising 14,604 sqm GEA office floorspace (Use Class B1), 1,450 sqm GEA retail floorspace (Use Class A1-A3), 13 residential units (Use Class C3), improvements to the public realm and all other necessary enabling works."*

150 Holborn is located in the London Borough of Camden (LBC), with this report detailing the acoustic design requirements that are pertinent to gaining planning approval. As such, the report makes references to standard guidance and LBC Development Policy 28 (DP28), which details the specific acoustic requirements for developments in the borough.

In order to assess the acoustic requirements of DP28, noise and vibration surveys have been completed within the building and surrounding area.

The noise survey was performed between 9 October 2015 and 20 October 2015. The noise survey method and results are provided in Appendix A. The results of the noise survey have been applied to set plant noise emission limits for the building services, to assess whether the position of the residential units is appropriate and provide an indication of the likely facade sound insulation requirements to meet standard criteria.

The vibration survey was performed on 13 October 2015 and 19 October 2015. The vibration survey method, results and analysis are provided in Appendix B. The results from the vibration survey have been used to demonstrate compliance with the relevant sections of DP28 relating to vibration and re-radiated noise from underground trains.

Contents

1 Introduction

Sandy Brown Associates LLP (SBA) has been commissioned by DAH Real Estate sarl to provide acoustic advice in relation to the proposed mixed use commercial led driven development at 150 Holborn, London, EC1.

The report presents standard guidance and local authority (London Borough of Camden) requirements relevant to commercial and residential buildings.

2 Site description

The site location in relation to its surroundings is shown in Figure 1 and Figure 2.

The site is located at 150 Holborn, which is bound by Gray's Inn Road to the west, Brooke Street to the east and Holborn to the south.

Chancery Lane tube station lies to the south of the site, servicing trains on the central line of the London Underground. Figure 2 illustrates the approximate location of the underground train route, which is shown to follow Holborn.

The site is located in the London Borough of Camden (LBC), with the boundary of the City of London (CoL) on the southern side of Holborn.

Figure 1 Site map (courtesy of Google Earth Pro)

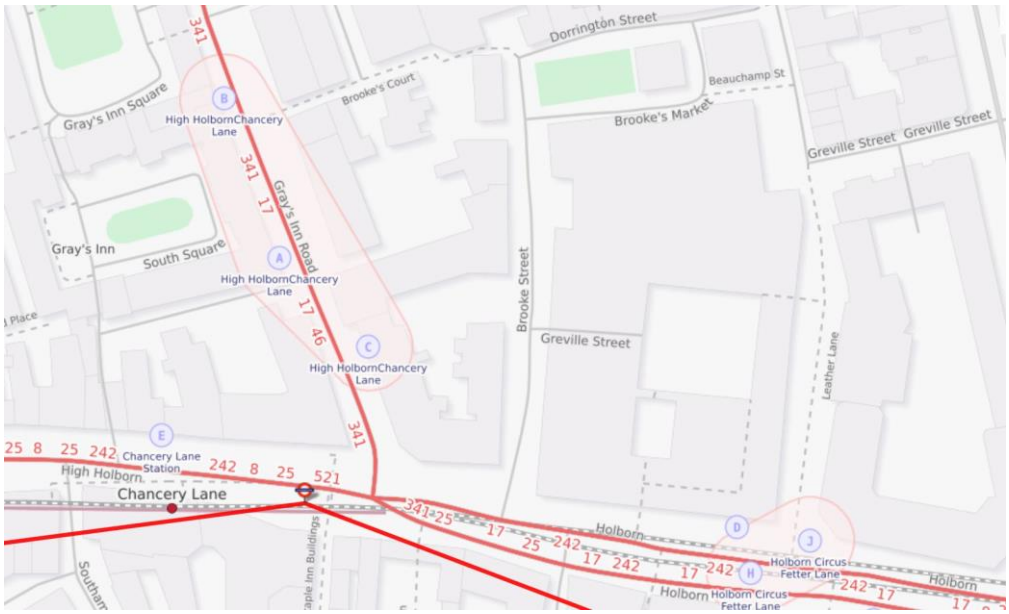

Figure 2 Site map showing the location of the central line to the south

2.1 Nearby noise sensitive receptors

To the north of the site, on the property boundary is a vacant commercial building. Further north, approximately 60 m from the property boundary, are residential properties known as Brookes Court.

To the east of the site across Brooke Street, approximately 10 m from the development property boundary, is the commercial property Waterhouse Square.

To the south of the site across Holborn, approximately 30 m from the development boundary, is commercial property 337 Holborn.

To the west across Gray's Inn road, approximately 20 m from the development property boundary, are retail and residential properties.

3 Assessment criteria

The assessment criteria relevant to the planning process has been based on London Borough of Camden (LBC) Development Policy 28 (DP28) and standard guidance.

The following categories have therefore been assessed:

- External noise environment
- Plant noise emission limits
- Internal noise levels – noise ingress
- Tactile vibration in the buildings
- Re-radiated noise levels in the residential dwellings.

Each of the above have been addressed in the following sections, with specific references being made to the noise and vibration data presented in Appendix A and B respectively.

3.1 External noise levels for residential developments

3.1.1 NPPF and NPSE

The National Planning Policy Framework (NPPF) sets out the government planning requirements, and supersedes previous guidance notes such as PPG24. No specific noise criteria are set out in the NPPF, or in the Noise Policy Statement for England (NPSE) to which it refers.

The NPPF states:

'Planning policies and decisions should aim to:

- *Avoid noise from giving rise to significant adverse impacts on health and quality of life as a result of new development;*
- *Mitigate and reduce to a minimum other adverse impacts on health and quality of life arising from noise from new development, including through the use of conditions;*
- *Recognise that development will often create some noise and existing businesses wanting to develop in continuance of their business should not have unreasonable restrictions put on them because of changes in nearby land uses since they were established; and*
- *Identify and protect areas of tranquillity which have remained relatively undisturbed by noise and are prized for their recreational and amenity value for this reason.'*

The NPSE states that its aims are as follows:

'Through the effective management and control of environmental, neighbour and neighbourhood noise within the context of Government policy on sustainable development:

- *Avoid significant adverse impacts on health and quality of life;*
- *Mitigate and minimise adverse impacts on health and quality of life; and*
- *Where possible, contribute to the improvement of health and quality of life.'*

As such, although neither of these documents sets out specific acoustic criteria for new residential development, the requirement to control both the effect of existing noise on the new development and the effect of noise from the development on the surroundings needs to be considered.

3.1.2 Local authority requirements

LBC assesses the suitability of a residential application on an interpretation of the superseded PPG 24.

Table A of DP28 sets out the external facade ambient noise levels where planning permission for residential developments will not normally be granted. The external noise limits from Table A for when the sites are adjacent to roads, is reproduced in Table 1.

Table 1 Noise levels on residential sites at which planning permission will not be granted

Day (0700-1900)	Evening (1900-2300)	Night (2300-0700)
L_{Aeq12h} 72 dB	L_{Aeq4h} 72 dB	L_{Aeq8h} 66 dB

Table B of DP28 sets out the minimum external facade ambient noise levels where attenuation measures will be required for residential developments. The external noise levels from Table B for when the sites are adjacent to roads, is reproduced in Table 2.

Table 2 Noise levels on residential sites at which attenuation will be required

Day (0700-1900)	Evening (1900-2300)	Night (2300-0700)
L_{Aeq12h} 62 dB	L_{Aeq4h} 57 dB	L_{Aeq8h} 52 dB

3.2 External noise levels – noise egress

3.2.1 Standard guidance

Guidance for noise emission from proposed new items of building services plant is given in BS 4142: 2014 *'Methods for rating and assessing industrial and commercial sound'*.

BS 4142 provides a method for assessing noise from items such as building services plant against the existing background sound levels at the nearest noise sensitive.

BS 4142 suggests that if the noise level is 10 dB or more higher than the existing background sound level, it is likely to be an indication of a significant adverse impact. If the level is 5 dB above the existing background sound level, it is likely to be an indication of an adverse impact. If the level does not exceed the background level, it is an indication of having a low impact.

If the noise contains 'attention catching features' such as tones, bangs etc, a penalty, based on the type and impact of those features, is applied.

3.2.2 Local authority

LBC requirements relating to noise emissions from building services are located in Table E of DP28, which is reproduced in Table 3.

Table 3 LBC plant noise emission limits taken from Table E of DP28

Noise description and location of measurement	Period	Time	Noise Level
Noise at 1 metre externa to a sensitive facade	Day, evening and night	0000-2400	5 dB < L_{A90}
Noise that has a distinguishable discrete continuous note (whine, hiss, screech, hum) at 1 metre external to a sensitive facade.	Day, evening and night	0000-2400	10 dB < L_{A90}
Noise that has distinct impulses (bangs, clicks, clatters, thumps) at 1 metre external to a sensitive facade	Day, evening and night	0000-2400	10 dB < L_{A90}
Noise at 1 metre external to a sensitive facade where L_{A90} >60 dB	Day, evening and night	0000-2400	5 dB < L_{A90}

3.3 Internal noise level – noise ingress

3.3.1 Standard guidance

Guidance on acceptable internal noise levels in residential dwellings is given in BS 8233:2014 *Sound insulation and noise reduction for buildings*, and is also provided by the World Health Organisation. The guidance given by BS 8233 and WHO is shown in Table 4.

Table 4 Internal noise criteria for sleeping/resting

Internal space	Indoor ambient noise level L_{Aeq} (dB)		
	BS 8233 (07:00 to 23:00)	BS 8233 (23:00 to 07:00)	WHO
Living rooms	35	-	30/35[1]
Dining room	40	-	-
Bedrooms	35	30[2]	30[2]

[1] WHO does not differentiate between different types of living spaces, but recommends L_{Aeq} 30 dB in relation to sleep disturbance and L_{Aeq} 35 dB in relation to speech intelligibility. WHO provides a 16 hour time base when referring to speech intelligibility and an 8 hour time base when referring to sleep disturbance.

[2] BS 8233 notes that individual noise events can cause sleep disturbance, and that a guideline value may be set depending on the character and number of events per night, although no specific limit is provided. Section 3.4 of the WHO guidelines for community noise suggests that good sleep will not generally be affected if internal levels of L_{Amax} 45 dB are not exceeded more than 10-15 times per night.

3.3.2 Local authority requirements

LBC does not have specific criteria relating to acceptable internal noise levels within apartments from environmental noise sources. As such, the guidance provided in BS8233:2014 is assumed to be the most relevant.

3.4 Tactile vibration criteria

3.4.1 Standard guidance

Tactile vibration is that which is perceived as mechanical motion. BS 6472-1: 2008 *Guide to Evaluation of Human Exposure to Vibration in Buildings Part 1: Vibration Sources Other Than Blasting* provides procedures for assessing the potential human response to vibration.

Vibration is assessed in terms of the equivalent 'vibration dose value'. This relates the level and duration of vibration.

For information, the BS 6472-1: 2008 assessment table is reproduced below:

Table 5 BS 6472-1: 2008 tactile vibration assessment criteria

Vibration dose values ($m/s^{1.75}$) above which might result in various degrees of adverse comment within residential buildings.			
Place	Low probability of adverse comment	Adverse comment possible	Adverse comment probable
Residential buildings 16 hr day	0.2 to 0.4	0.4 to 0.8	0.8 to 1.6
Residential building 8 hr night	0.1 to 0.2	0.2 to 0.4	0.4 to 0.8

Note that offices and workshops, multiplying factors of 2 and 4 respectively should be applied to the above vibration dose value ranges for a 16 hr day.

It is important to note that people exhibit wide variations of vibration tolerance. Specific values are dependent upon social and cultural factors, psychological attitudes and expected degree of intrusion.

3.4.2 Local authority requirements

LBC requirements relating to tactile vibration in buildings is provided in Table C of DP28, which is reproduced in Table 6.

Table 6 LBC tactile vibration limits in buildings taken from Table C of DP28

Vibration description and location of measurement	Period	Time	Vibration Dose Value (VDV)
Vibration inside dwellings	Day and evening	0700-2400	0.2-0.4 $ms^{-1.75}$
Vibration inside dwellings	Night	2300-0700	0.13 $ms^{-1.75}$
Vibration inside offices	Day, evening and night	0000-2400	0.4 $ms^{-1.75}$

3.5 Re-radiated noise criteria

3.5.1 Standard guidance

There is currently no international or British Standard which provides guidance on assessing the impact of ground-borne noise from railways on the occupants of a building. The Association of Noise Consultants (ANC) guidelines '*Measurement and assessment of ground-borne noise and vibration*', 2nd edition published in 2012, is generally used as the basis of assessments such as this.

This document also provides discussion on the relevant research that has been carried out, and a summary of typically adopted criteria.

The most relevant items are set out below:

- The American Public Transit Association (APTA) guidelines recommend criteria of between 30 and 40 dB(A) depending on the density and type of residential properties. They do not define where within a building these apply, or the time response that should be used.
- The Federal Transit Administration (FTA) of the US Department of Transportation, recommends limits for maximum pass-by levels of 35 dB(A) for frequent events (more than 70 events per day) and 43 dB(A) for infrequent events.
- London Underground Limited has studied the relationship between ground-borne noise levels and complaint thresholds. This was used to define a complaint threshold of 40 dB L_{Amax}.
- The ANC guidelines also note that Local Authority guidelines for ground-borne noise were published in London and the South East, and state a limit of 35 dB L_{Amax}.
- With regards to offices, *British Council for Office Guide to Specification 2014 (BCO Guide)* states that re-radiated noise levels in occupied cellular offices and meeting rooms should be no more than L_{Amax} 45 dB, or 50 dB in open plan offices.

In all of the above examples, the time constant is not defined, with the exception of the Local Authority guidelines in London and the South East, which is defined as having a fast time weighting.

It should be noted that most of this research relates to residential accommodation, and is aimed at providing good sleeping / resting conditions.

3.5.2 Local authority requirements

DP28 states that "*Where dwellings may be affected by ground borne regenerated noise internally from, for example, railways or underground trains within tunnels noise levels within the rooms should not be greater than 35 dB(A)max".*

4 External noise level assessment

Section 4 of Appendix A presents the measured ambient noise levels around the development site.

The measured ambient noise levels at monitoring position L1 reflect the noise climate at the position of the proposed residential accommodation. The measured ambient noise levels at L1 are provided in Table 7.

Table 7 Ambient noise levels measured during the survey at position L1

Date	Daytime (07:00-19:00) $L_{Aeq,\ 12\ hour}$ (dB)	Evening (19:00-23:00) $L_{Aeq,\ 4\ hour}$ (dB)	Night (23:00-07:00) $L_{Aeq,\ 8\ hour}$ (dB)
Friday 9 October 2015	64[1]	63	58
Saturday 10 October 2015	60	59	58
Sunday 11 October 2015	59	59	57
Monday 12 October 2015	64	59	59
Tuesday 13 October 2015	64[2]	-	-
Weekday average	64	61	59
Weekend average	60	59	58

Inspection of Table 7 in relation to the DP28 requirements (Table 1 and Table 2) indicates that the proposed location of the residential accommodation complies with requirements and that planning application will not be rejected on the basis of high external noise levels. However, the design of the residential accommodation will need to adopt attenuation measures to control noise ingress.

5 Plant noise limits – noise egress

Section 4 of Appendix A summarizes the measured background noise levels around the development. Based on the DP28 criteria and the background noise measurements, the cumulative noise level resulting from the operation of all new plant at 1 m from the worst affected windows have been set.

5.1.1 Noise sensitive receptors along Brooke Street

The plant noise limits at the noise sensitive properties located along Brooke Street are not to exceed those presented in Table 8.

Table 8 Plant noise limits at 1 m from the nearest noise sensitive premises on Brooke Street

Day	Daytime (07:00-19:00) L_{Aeq} (dB)	Evening (19:00-23:00) L_{Aeq} (dB)	Night (23:00-07:00) L_{Aeq} (dB)
Weekday	50	49	42
Weekend	46	45	41

5.1.2 Noise sensitive receptors along Holborn

The plant noise limits at the noise sensitive properties located along Holborn are not to exceed those presented in Table 9.

Table 9 Plant noise limits at 1 m from the nearest noise sensitive premises on Holborn

Day	Daytime (07:00-19:00) L_{Aeq} (dB)	Evening (19:00-23:00) L_{Aeq} (dB)	Night (23:00-07:00) L_{Aeq} (dB)
Weekday	57	56	49
Weekend	53	53	47

5.1.3 Noise sensitive receptors along Gray's Inn Road

The plant noise limits at the noise sensitive properties located along Gray's Inn Road are not to exceed those presented in Table 10.

Table 10 Plant noise limits at 1 m from the nearest noise sensitive premises on Gray's Inn Road

Day	Daytime (07:00-19:00)	Evening (19:00-23:00)	Night (23:00-07:00)
	L_{Aeq} (dB)	L_{Aeq} (dB)	L_{Aeq} (dB)
Weekday	56	54	51
Weekend	53	53	50

5.1.4 Adjustments

The limits set out in Table 8 to Table 10 do not include any attention catching features. If the selected plant is tonal the proposed plant noise limits will need to be reduced by 5 dBA, ie a more stringent limit will need to be met.

5.2 Assessment

At this stage, no information is available in relation to the proposed installation of building services plant, and this will need to be assessed in detail as the design progresses. However, all plant items will be designed to achieve the plant noise limits set out above, including any corrections for attention catching features.

6 Facade sound insulation – noise ingress

This section discusses internal noise level criteria and assesses the required facade sound insulation performance. In principle, the required facade specification depends on two factors – the external noise levels at the site and the internal noise criteria.

The following assessment is based on achieving the internal noise levels recommended in BS 8233:2014 for residential accommodation only, which are defined in Section 3.3.1.

6.1 External noise levels

In order to allow an assessment of the worst case scenario, the highest noise levels provided in Table 7 have been used to assess noise ingress, ie $L_{Aeq,12hrs}$ 64 dB during the daytime and $L_{Aeq,8hrs}$ 59 dB during the night time.

6.2 Facade sound insulation

To achieve the internal noise criteria given in Section 3.3.1 for bedrooms and other living areas minimum facade sound insulation requirements have been determined, based on the external noise levels at each facade stated above.

The sound insulation performances for the residential facades will be in the region of $R_w + C_{tr}$ 31 dB.

It is noted that the above sound insulation performance can be achieved with a laminated double glazing unit and attenuated passive ventilation. As the design progresses, a more detailed facade sound insulation assessment will be performed to ensure that the overall performance requirements will be met.

7 Vibration assessment

7.1 Tactile vibration

Table 3 in Section 6.1 of Appendix B presents the results from the assessment of tactile vibration in a number of positions in the existing building. The results from the survey indicate that the maximum VDV experienced in the existing building is in the order of 0.05 $ms^{-1.75}$.

The measured VDVs are significantly below the DP28 tactile vibration criteria for commercial or residential buildings.

7.2 Re-radiated noise

Table 4 in Section 6.2 of Appendix B presents the results relating to the predicted re-radiated noise in the existing building.

Further to the results, analysis has been completed on the likely highest levels of re-radiated noise that can be expected in the residential accommodation. The analysis, based on worst-case assumptions, indicates maximum events in the order of L_{ASmax} 34 dB may be experienced in the completed building.

The predicted re-radiated noise levels are below the DP 28 re-radiated noise criterion for residential dwellings.

8 Conclusion

Sandy Brown Associates LLP (SBA) has assessed the external noise environment and the internal vibration levels for the development of 150 Holborn, London, EC1. The development is located in the London Borough of Camden (LBC).

The assessment has been completed with regards to the measurements detailed in Appendices A and B, standard guidance and the LBC Development Policy 28 (DP28).

The results from the noise measurements have been used to confirm that the proposed location of the residential accommodation forming part of the development is located in a suitable location, where planning permission will normally be granted. However, the design of the residential units will need to consider attenuation measures in order to achieve suitable internal noise conditions, with provisional guidance provided on how these can be achieved.

In addition, the noise measurements have been used to set plant noise emission limits. The actual plant noise emissions will need to be assessed when details on the location and equipment have been decided.

The vibration measurements completed indicate that the level of tactile vibration experienced in the offices and residential accommodation will meet the relevant criteria without the need to vibration isolate the building.

In addition, the vibration measurements have been used to assess the worst-case levels of re-radiated noise in the residential accommodation. The analysis completed indicates that a level of L_{ASmax} 34 dB may be experienced in the dwellings, which is below the criterion presented in DP28.

Appendix A

Environmental noise survey report

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15374-R01-B

7 March 2016

150 Holborn

Environmental noise survey report

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Version	Date	Comments	Author	Reviewer
A	30 Oct 15		Richard Deane	Andrew Long
B	7 Mar 16		Philip Owen	Stephen Stringer

Summary

Sandy Brown Associates LLP (SBA) has been commissioned by DAH Real Estate sarl to provide acoustic advice in relation to the proposed mixed use commercial led development at 150 Holborn.

An environmental noise survey has been carried out to determine the existing background and ambient sound levels in the area. The noise survey was performed between 13:35 on 9 October 2015 and 15:50 on 20 October 2015.

The environmental noise survey consisted of unattended long term noise monitoring and attended measurements that were used to supplement the long term monitoring.The representative background sound levels were found to range from 48 to 62 dB. The ambient noise level measured was found to range from 57 to 72 dB. These noise levels will be used to assess facade noise levels and noise ingress, and to control noise emissions from building services plant.

The measured noise levels will be used to set noise emission limits for a future assessment of building services plant, and to provide advice on the facade sound insulation requirements.

Contents

1 Introduction

Sandy Brown Associates LLP (SBA) has been commissioned by DAH Real Estate sarl to provide acoustic advice in relation to the proposed development at 150 Holborn.

In order to provide acoustic design advice, an environmental noise survey has been undertaken. The purpose of the survey is to establish the existing background and ambient sound levels in the vicinity of the building to base plant noise emission levels upon and provide facade sound insulation advice.

This report presents the method and results of the environmental noise survey.

2 Site description

2.1 The site and its surrounding

The site location in relation to its surroundings is shown in Figure 1. The site is located at 150 Holborn, with Grays Inn Road to the west and Brooke Street to the east. The site falls into the London Borough of Camden (LBC), with the boundary of the City of London (CoL) being just to the south of Holborn. Chancery lane tube station lies to the south of the site, servicing trains on the central line of the London Underground.

The site is adjacent to ground floor retail buildings on the south facade, residential to the west and a Grade 2 listed office building to the east.

Figure 1 Site map (courtesy of Google Earth Pro)

3 Method

Details of the equipment used, the noise indices, and the weather conditions during the survey are provided in Appendix A. Further information on the specific survey method is provided in this section.

3.1 Unattended measurements

Unattended noise monitoring was undertaken at three positions on the site over 11 days to determine the existing sound levels in the vicinity of 150 Holborn.

The unattended measurements were performed over 5 minute periods between 13:35 on 9 October 2015 and 15:50 on 20 October 2015. The equipment was installed and collected by Philip Owen and Richard Deane.

The measurement positions used during the survey are indicated in Figure 2, denoted by the letters 'L1', 'L2' and 'L3'. Photographs showing the measurement locations are provided in Figure 3.

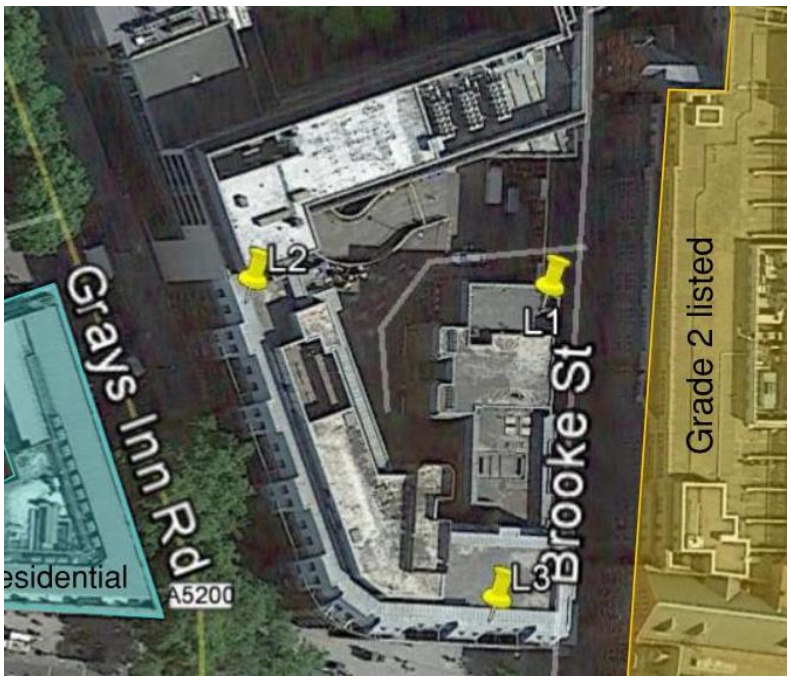


Figure 2 Photograph showing location of long term unattended measurement positions

Figure 3 Photograph showing location of L1, L3 and the view from L2

The unattended noise logger positions were as follows:

- L1 - installed within a 2nd floor room facing Brooke Street, with the microphone mounted on a boom protruding from the window
- L2 - installed within a 6th floor room facing Holborn, with the microphone mounted on a boom protruding from the window behind a permeable screen
- L3 - installed within a 6th floor room facing Grays Inn Road, with the microphone mounted on a boom protruding from the window

These locations were chosen to be reasonably representative of the noise levels experienced in the vicinity of 150 Holborn.

3.2 Attended measurements

Attended sample measurements were performed by Francis Goodall at ground level directly beneath long term monitoring positions L2 and L3. The attended measurements were carried out on 20 October 2015, over 5 minute periods. The main purpose of the measurements was to evaluate the difference between the noise levels experienced at ground level and those measured at the monitoring positions that were at higher levels. Photographs showing the measurement locations are provided in Figure 4 to Figure 6.

In each case the microphone was mounted on a tripod approximately 1.5 m above the ground level and approximately 1 m from the facade of the existing building at 150 Holborn.

Figure 4 Photograph showing the location of attended measurements on Holborn

Figure 5 Photograph showing the location of attended measurements on Grays Inn Road

Figure 6 Photograph showing the location of attended measurements on Brooke Street

4 Measurement results

4.1 Observations

The dominant noise sources observed at the site during the survey consisted of traffic from Holborn and Grays Inn Road. Other noise sources included pedestrians and occasional aircraft.

4.2 Unattended measurement results

The results of the unattended noise measurements are summarised in the following sections. Graphs showing the results of the unattended measurements are provided in Appendix B.

Period-averaged ambient sound levels ($L_{Aeq,T}$) have been derived for each position along with representative background sound levels. Representative background sound levels have been derived in line with guidance set out within BS 4142:2014. These have been quantified using a statistical analysis of the continuous logging measurements as presented in appendix C.

4.2.1 Position L1

The day and night time ambient noise levels measured during the unattended survey at position L1 are presented in Table 1.

Measurements at position L1 were facade measurements, and as such a 3 dB correction would need to be applied to derive free-field noise levels.

Table 1 Ambient noise levels measured during the survey at position L1

Date	Daytime (07:00-19:00) $L_{Aeq,\ 12\ hour}$ (dB)	Evening (19:00-23:00) $L_{Aeq,\ 4\ hour}$ (dB)	Night (23:00-07:00) $L_{Aeq,\ 8\ hour}$ (dB)
Friday 9 October 2015	64[1]	63	58
Saturday 10 October 2015	60	59	58
Sunday 11 October 2015	59	59	57
Monday 12 October 2015	64	59	59
Tuesday 13 October 2015	64[2]	-	-
Weekday average	64	61	59
Weekend average	60	59	58

[1] result averaged over 4.5 hour measurement duration

[2] result averaged over 8.5 hour measurement duration

The representative background sound levels measured during the unattended survey are given in Table 2.

Table 2 Representative background sound levels measured during the survey at position L1

Day	Daytime (07:00-19:00) $L_{A90,5min}$ (dB)	Evening (19:00-23:00) $L_{A90,5min}$ (dB)	Night (23:00-07:00) $L_{A90,5min}$ (dB)
Weekday	55	54	47
Weekend	51	50	46

4.2.2 Position L2

The day and night time ambient noise levels measured during the unattended survey at position L2 are presented in Table 3.

Measurements at position L2 were facade measurements, and as such a 3 dB correction would need to be applied to derive free-field noise levels.

Table 3 Ambient noise levels measured during the survey at position L2

Date	Daytime (07:00-19:00) $L_{Aeq,\ 12\ hour}$ (dB)	Evening (19:00-23:00) $L_{Aeq,\ 4\ hour}$ (dB)	Night (23:00-07:00) $L_{Aeq,\ 8\ hour}$ (dB)
Tuesday 13 October 2015	68[1]	68	64
Wednesday 14 October 2015	68	67	66
Thursday 15 October 2015	68	68	65
Friday 16 October 2015	68	66	65
Saturday 17 October 2015	66	66	65
Sunday 18 October 2015	65	65	63
Monday 19 October 2015	67	66	65
Tuesday 20 October 2015	68[2]	-	-
Weekday average	68	67	65
Weekend average	66	66	64

[1] result averaged over 2 hour measurement duration

[2] result averaged over 9 hour measurement duration

The representative background sound levels measured during the unattended survey are given in Table 4.

Table 4 Representative background sound levels measured during the survey at position L2

Day	Daytime (07:00-19:00) $L_{A90,5min}$ (dB)	Evening (19:00-23:00) $L_{A90,5min}$ (dB)	Night (23:00-07:00) $L_{A90,5min}$ (dB)
Weekday	62	61	54
Weekend	58	58	52

4.2.3 Position L3

The day and night time ambient noise levels measured during the unattended survey at position L3 are presented in Table 5.

Measurements at position L3 were facade measurements, and as such a 3 dB correction would need to be applied to derive free-field noise levels.

Table 5 Ambient noise levels measured during the survey at position L3

Date	Daytime (07:00-19:00) $L_{Aeq, 12\ hour}$ (dB)	Evening (19:00-23:00) $L_{Aeq, 4\ hour}$ (dB)	Night (23:00-07:00) $L_{Aeq, 8\ hour}$ (dB)
Thursday 15 October 2015	67[5]	67	64
Friday 16 October 2015	67	65	64
Saturday 17 October 2015	64	64	63
Sunday 18 October 2015	63	64	62
Monday 19 October 2015	66	65	63
Tuesday 20 October 2015	67[6]	-	-
Weekday average	67	66	64
Weekend average	64	64	63

[5] result averaged over 9 hour measurement duration

[6] result averaged over 2 hour measurement duration

The representative background sound levels measured during the unattended survey are given in Table 6.

Table 6 Representative background sound levels measured during the survey at position L3

Day	Daytime (07:00-19:00) $L_{A90,5min}$ (dB)	Evening (19:00-23:00) $L_{A90,5min}$ (dB)	Night (23:00-07:00) $L_{A90,5min}$ (dB)
Weekday	61	59	56
Weekend	58	58	55

4.3 Attended measurement results

The sound pressure levels recorded and the dominant source of noise during the attended measurements are summarised in Table 7.

All the attended measurements were performed over 5 minute periods.

Measurements at all positions were facade measurements.

Table 7 Summary of attended noise measurements

Logger position directly above	Start time	$L_{Aeq,5min}$ at ground (dB)	$L_{Aeq,5min}$ at logger (dB)	Noise sources
L2	15:30	69	67	Road traffic, pedestrians
L2	15:45	71	67	Road traffic, pedestrians
L3	15:35	71	66*	Road traffic, pedestrians, queueing traffic
L3	15:50	71	67*	Road traffic, pedestrians, queueing traffic

*Simultaneous measurements were not possible at L3 and as such a logarithmic average of the L_{Aeq} at the respective time on previous days is presented.

Table 7 shows a difference of around 2-4 dB in the sound pressure levels measured at ground and 6th floor level at L2 and a difference of 4-5 dB at L3.

5 Conclusion

A noise survey has been carried out to determine the existing and ambient background sound levels in the vicinity of the site and surrounding noise sensitive premises. The representative background sound levels were found to range from 48 dB to 62 dB. The ambient noise level measured was found to range from 57 dB to 72 dB.

Attended measurements showed ambient noise levels at ground level to be 2-5 dB less than those measured at the sixth floor. There was no notable difference between ambient noise levels measured at the second and ground floor.

The measured noise levels can be used to set noise egress limits for a future assessment of building services plant, and to assess the levels of noise ingress to the site.

Appendix A

Survey details

Equipment

A Rion NL52 sound level meter and a Svantek 957 sound level meter were used to undertake the unattended measurements. The attended measurements were carried out using a Brüel & Kjær 2260 sound level meter. The calibration details for the equipment used during the survey are provided in Table A1.

Table A1 Equipment calibration data

Equipment description	Type/serial number	Manufacturer	Calibration expiry	Calibration certification number
Sound level meter	NL-52/00242702	Rion	4 Jun 17	1506331
Microphone	UC-59/06185	Rion	4 Jun 17	1506331
Pre-amp	NH-25/32730	Rion	4 Jun 17	1506331
Calibrator	CAL200/4499	Larson Davis	4 Jun 17	1506327
Sound level meter	SVAN957/12327	Svantek	25 Oct 15	1310490
Microphone	ACO7052H/43273	Svantek	25 Oct 15	1310490
Pre-amp	SV12L/13569	Svantek	25 Oct 15	1310490
Calibrator	SV30A/7451	Svantek	24 Oct 15	1310484
Sound level meter	2260/2553982	Bruel & Kjaer	22 May 17	CDK1503819
Microphone	4189/2978316	Bruel & Kjaer	22 May 17	CDK1503819
Pre Amp	ZC0026/4584	Bruel & Kjaer	22 May 17	CDK1503819
Calibrator	4231/2558390	Bruel & Kjaer	21 May 17	CDK1503794

Calibration of the sound level meters used for the tests is traceable to national standards. The calibration certificates for the sound level meters used in this survey are available upon request.

The sound level meters and microphones were calibrated at the beginning and end of the measurements using their respective sound level calibrators. No significant deviation in calibration occurred.

Noise indices

The equipment was set to record a continuous series of broadband sound pressure levels. Noise indices recorded included the following:

- $L_{Aeq,T}$ The A-weighted equivalent continuous sound pressure level over a period of time, T.
- $L_{AFmax,T}$ The A-weighted maximum sound pressure level that occurred during a given period with a fast time weighting.
- $L_{A90,T}$ The A-weighted sound pressure level exceeded for 90% of the measurement period. Indicative of the background sound level.

The L_{A90} is considered most representative of the background sound level for the purposes of complying with any local authority requirements.

Sound pressure level measurements are normally taken with an A-weighting (denoted by a subscript 'A', eg L_{A90}) to approximate the frequency response of the human ear.

A more detailed explanation of these quantities can be found in BS7445: Part 1: 2003 *Description and measurement of environmental noise, Part 1. Guide to quantities and procedures.*

Weather conditions

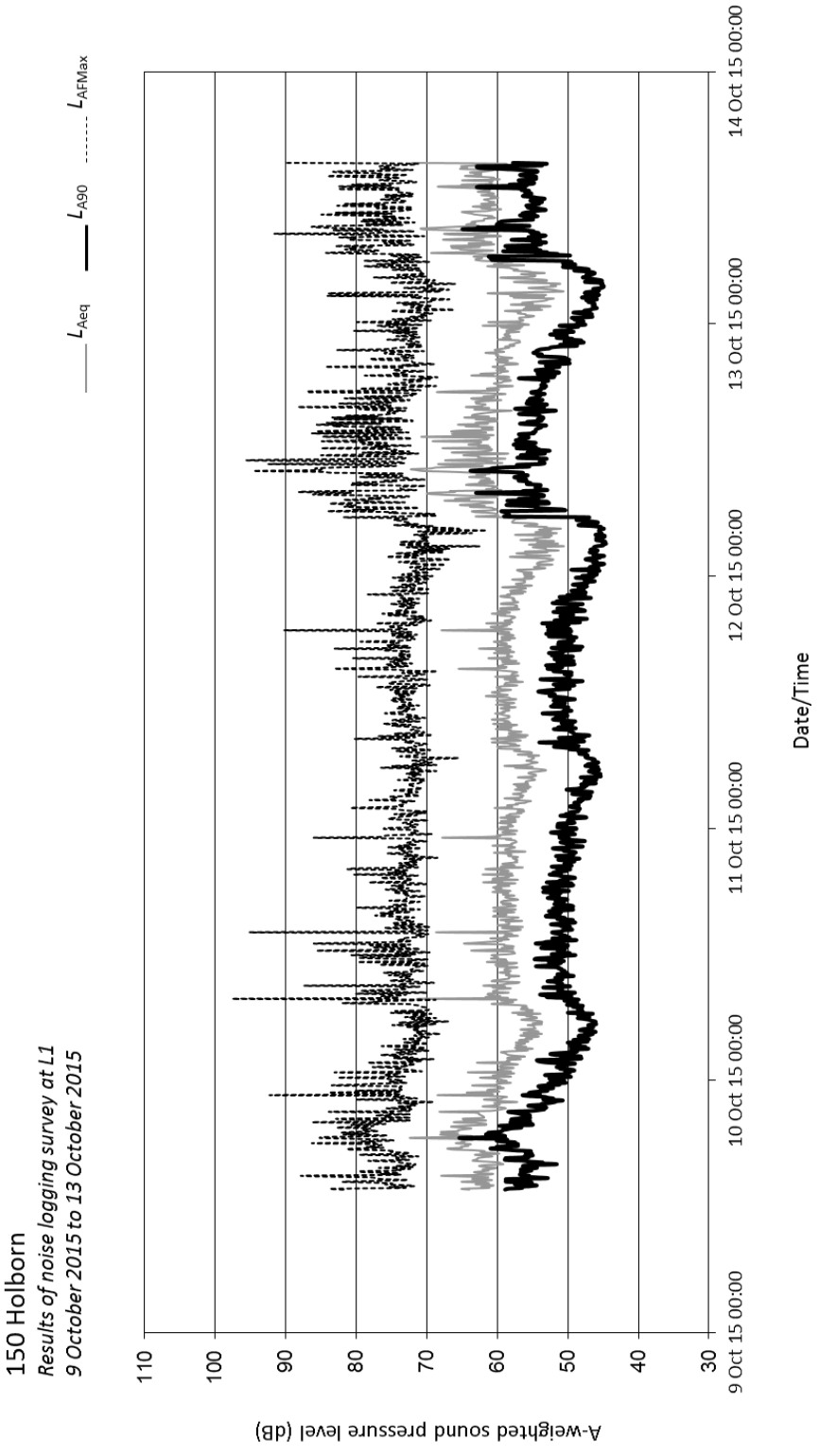
During the attended measurements carried out on 20 October 2015, the weather was generally clear and dry and no rain occurred. Wind speeds varied between approximately 2 m/s and 4.7 m/s.

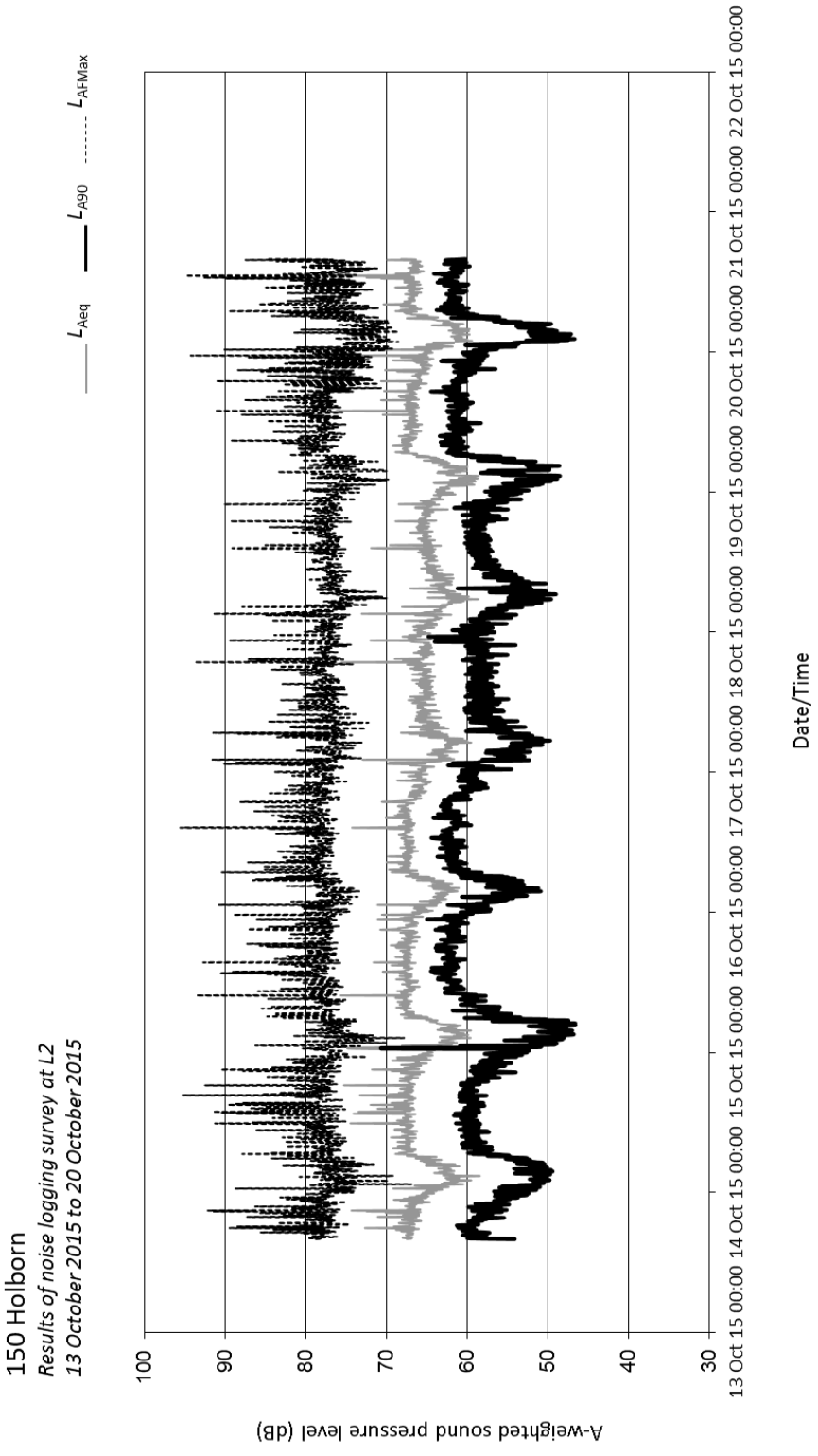
During the unattended noise measurements between 9 October 2015 and 20 October 2015, weather reports for the area indicated that temperatures varied between 8°C at night and 17°C during the day, and the wind speed was less than 6.7 m/s.

These weather conditions are considered suitable for obtaining representative measurements.

Appendix B

Results of unattended measurements at Locations L1, L2 and L3


150 Holborn
Results of noise logging survey at L1
9 October 2015 to 13 October 2015
LAeq
LA90
LAFMax
A-weighted sound pressure level (dB)
110
100
90
80
70
60
50
40
30
9 Oct 15 00:00
10 Oct 15 00:00
11 Oct 15 00:00
12 Oct 15 00:00
13 Oct 15 00:00
14 Oct 15 00:00
Date/Time


150 Holborn
Results of noise logging survey at L2
13 October 2015 to 20 October 2015
LAeq
LA90
LAFMax
A-weighted sound pressure level (dB)
100
90
80
70
60
50
40
30
13 Oct 15 00:00
14 Oct 15 00:00
15 Oct 15 00:00
16 Oct 15 00:00
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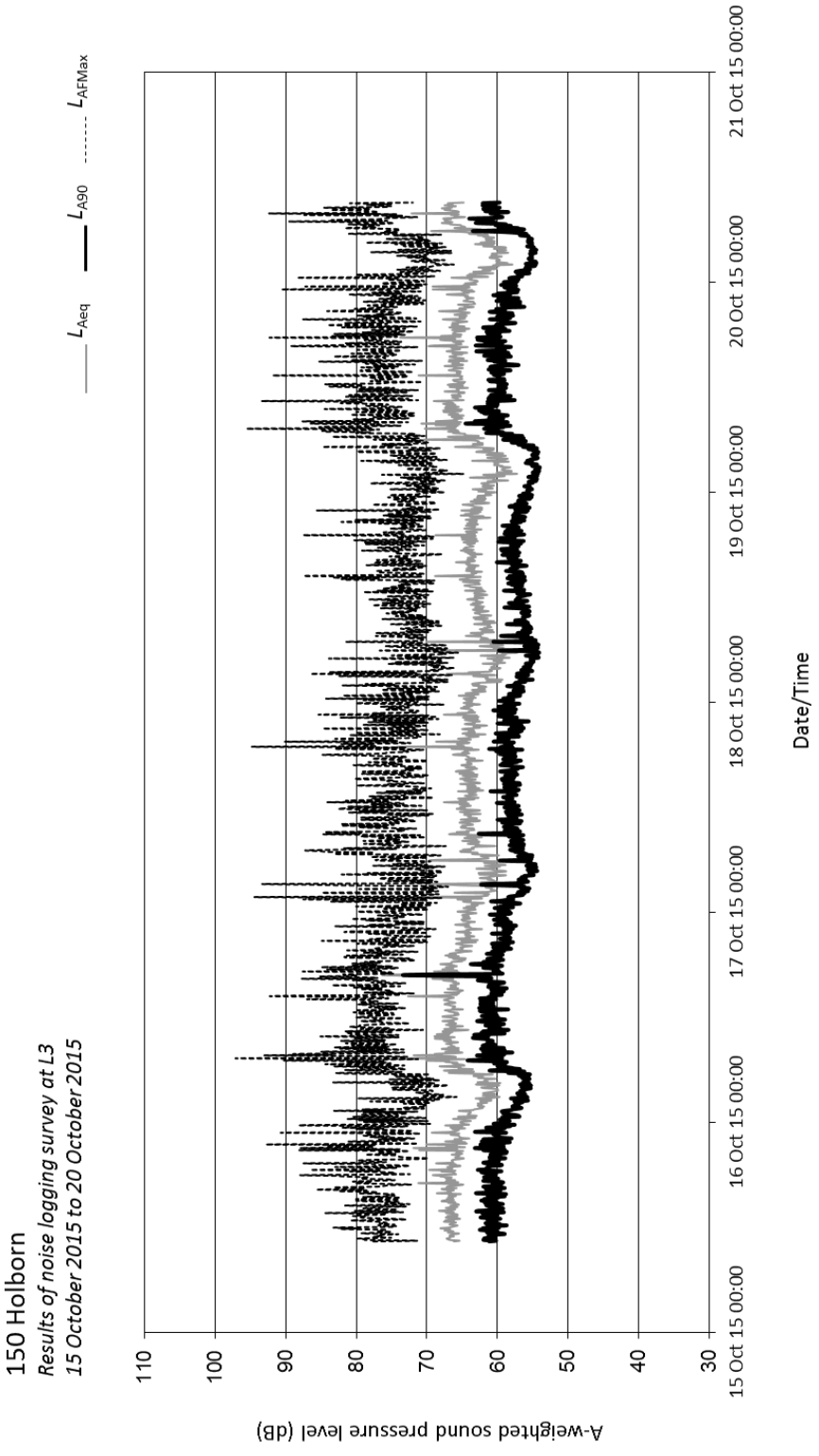
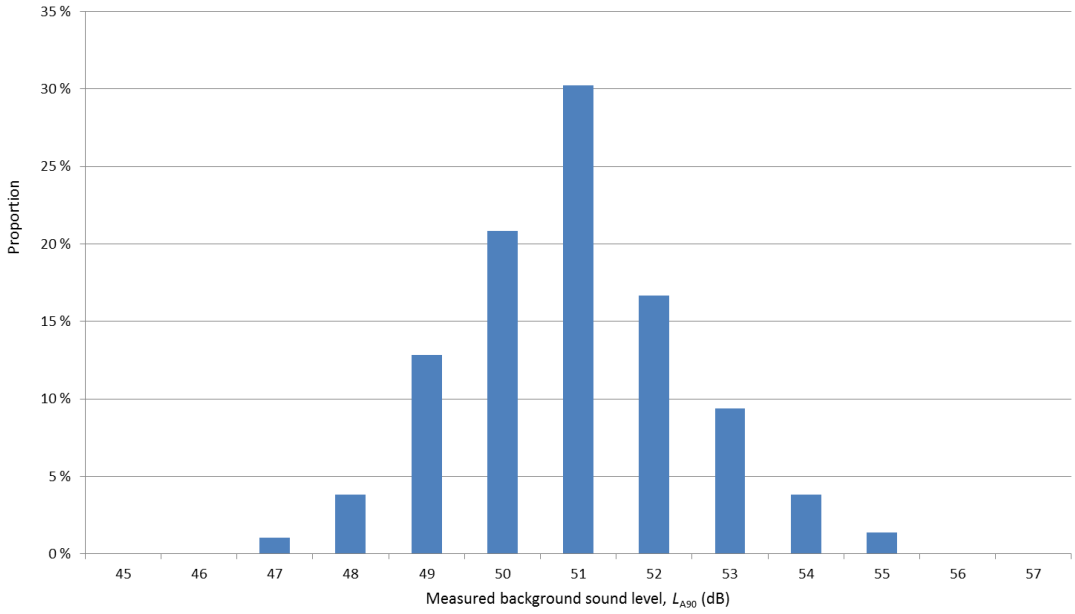
21 Oct 15 00:00
22 Oct 15 00:00
Date/Time


150 Holborn
Results of noise logging survey at L3
15 October 2015 to 20 October 2015
L_{Aeq}
L_{A90}
L_{AFMax}
A-weighted sound pressure level (dB)
110
100
90
80
70
60
50
40
30
15 Oct 15 00:00
16 Oct 15 00:00
17 Oct 15 00:00
18 Oct 15 00:00
19 Oct 15 00:00
20 Oct 15 00:00
21 Oct 15 00:00
Date/Time

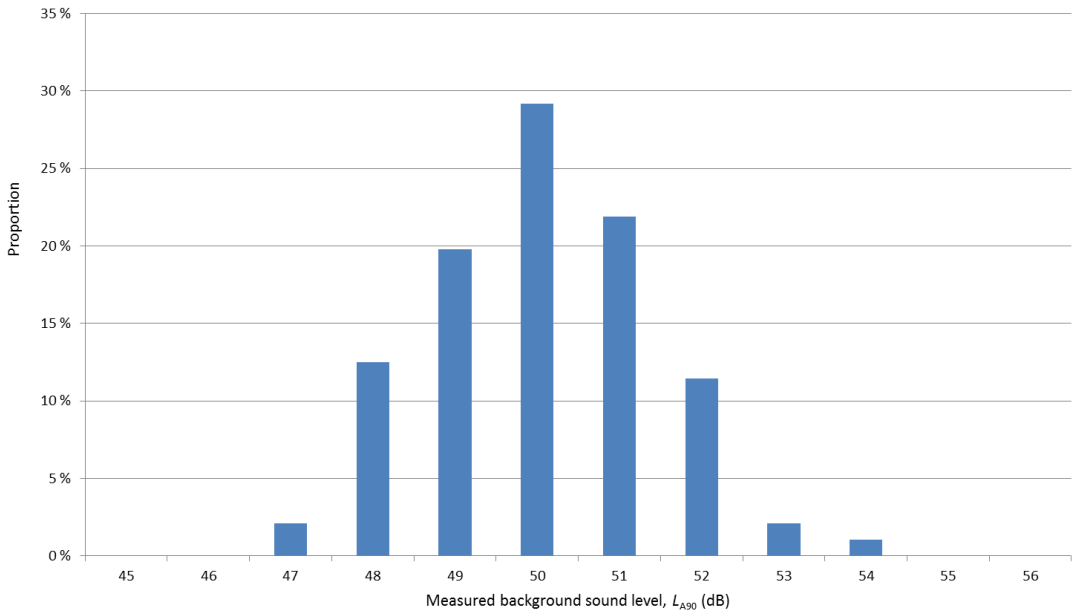
Appendix C

Statistical analysis of background sound levels at locations L1, L2 and L3

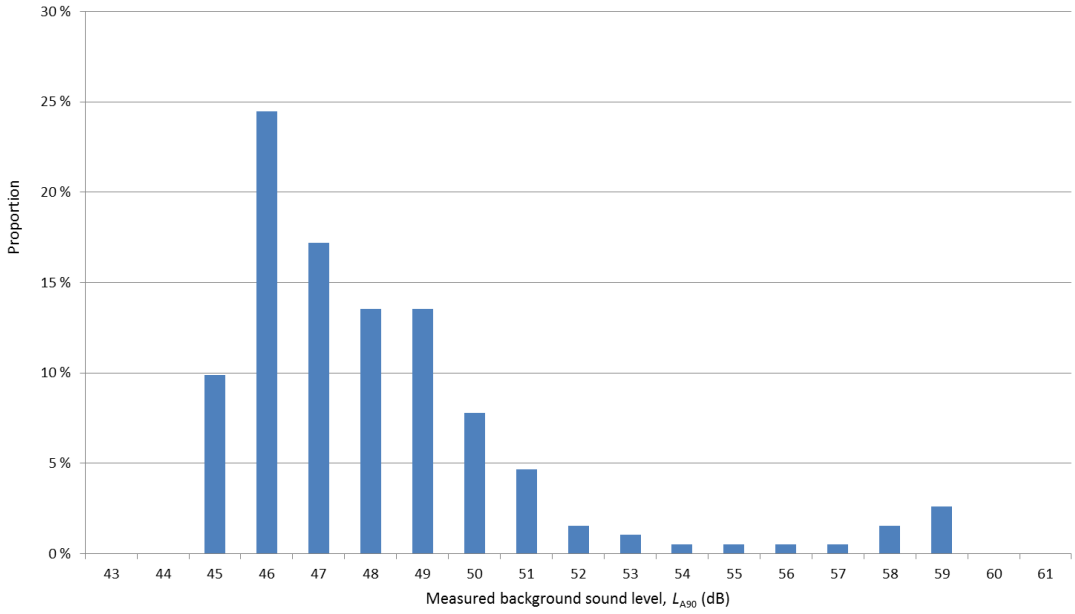
150 Holborn
Statistical analysis of commercial daytime background sound level at L1
9 October 2015 to 13 October 2015
Weekend daytime period (07:00 to 19:00 hours)



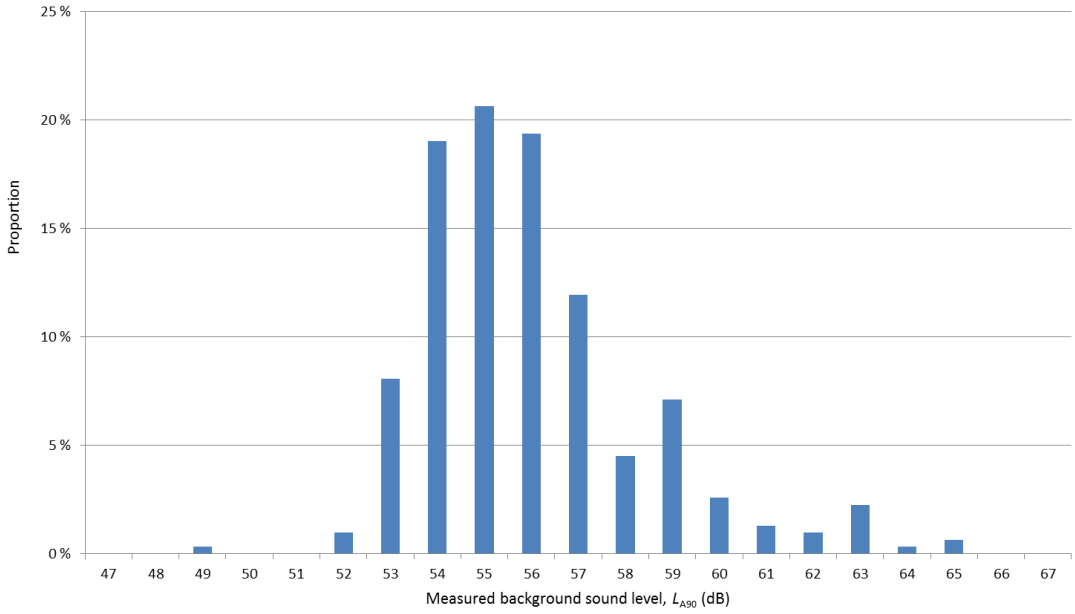
150 Holborn
Statistical analysis of evening background sound level at L1
9 October 2015 to 13 October 2015
Weekend evening period (19:00 to 23:00 hours)



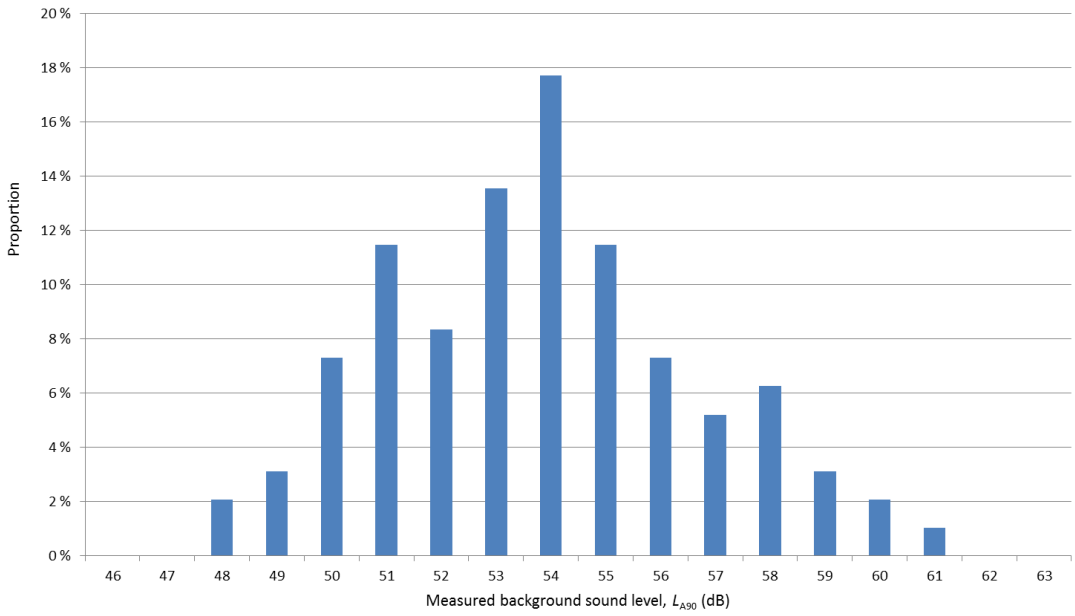
150 Holborn
Statistical analysis of night time background sound level at L1
9 October 2015 to 13 October 2015
Weekend night-time period (23:00 - 07:00 hours)



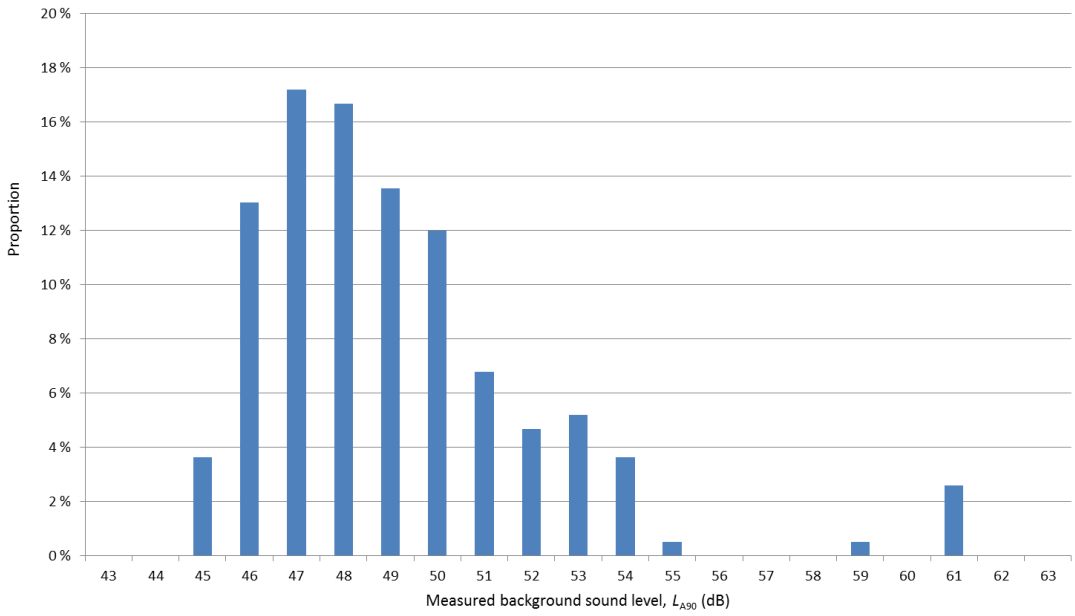
150 Holborn
Statistical analysis of commercial day time background sound level at L1
9 October 2015 to 13 October 2015
Weekday daytime period (07:00 to 19:00 hours)



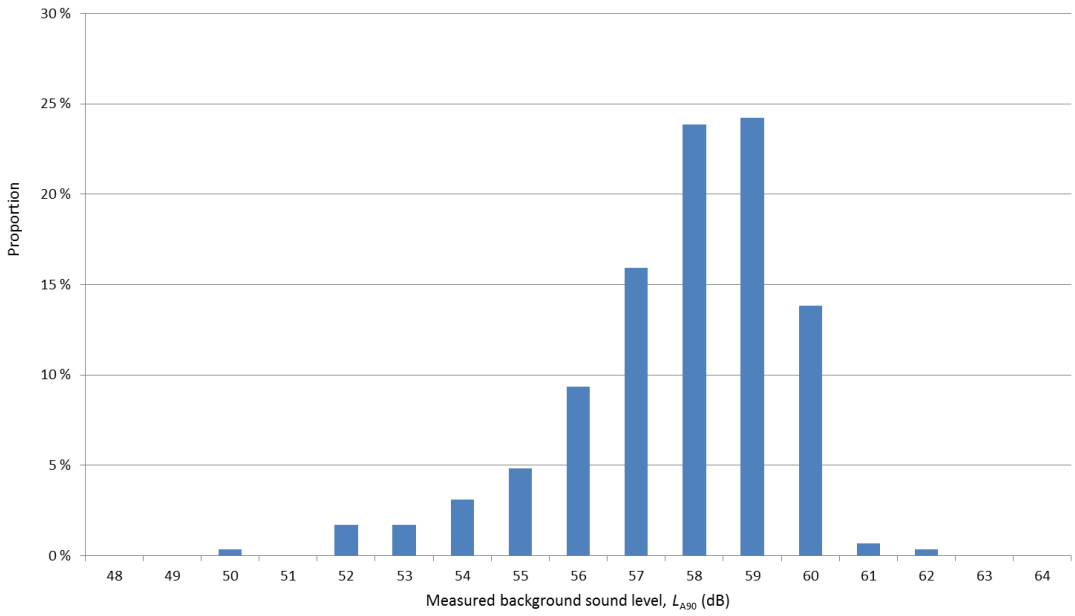
150 Holborn
Statistical analysis of evening background sound level at L1
9 October 2015 to 13 October 2015
Weekday evening period (19:00 to 23:00 hours)



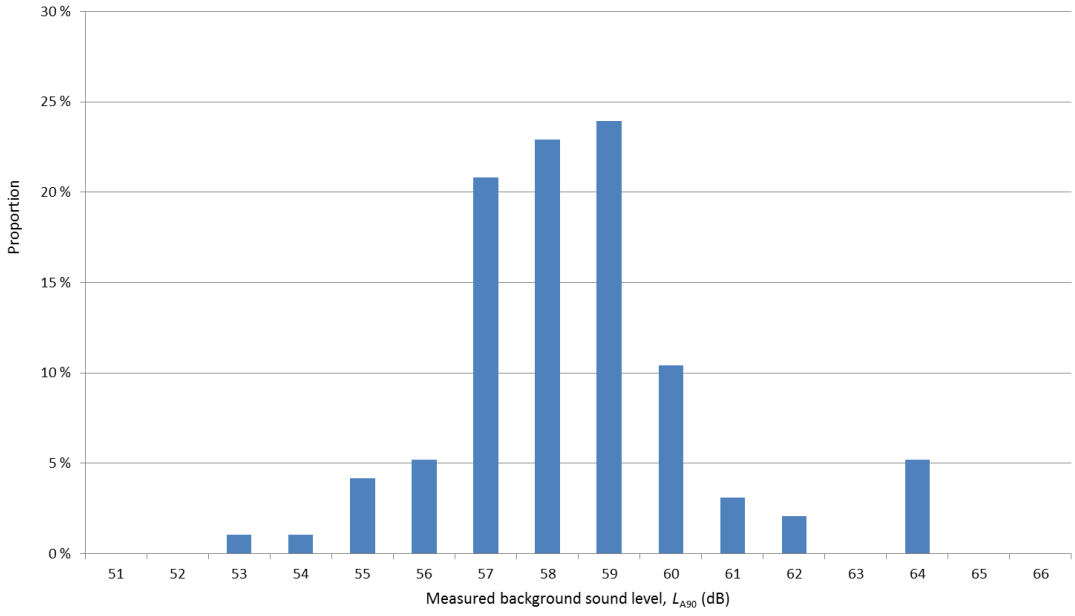
150 Holborn
Statistical analysis of night time background sound level at L1
9 October 2015 to 13 October 2015
Weekday night-time period (23:00 - 07:00 hours)



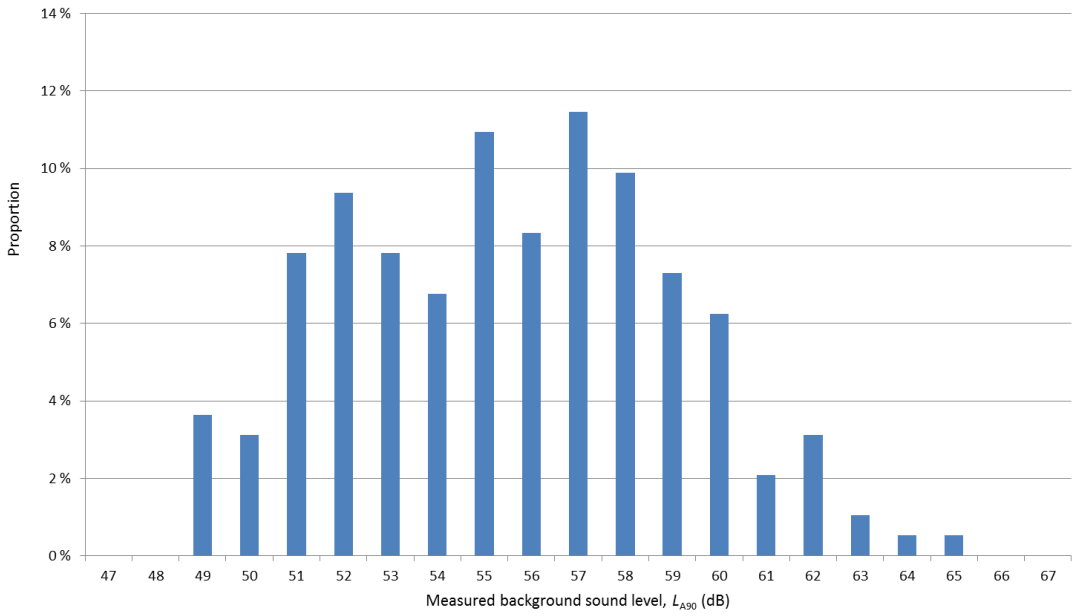
150 Holborn
Statistical analysis of commercial day time background sound level at L2
13 October 2015 to 20 october 2015
Weekend daytime period (07:00 to 19:00 hours)



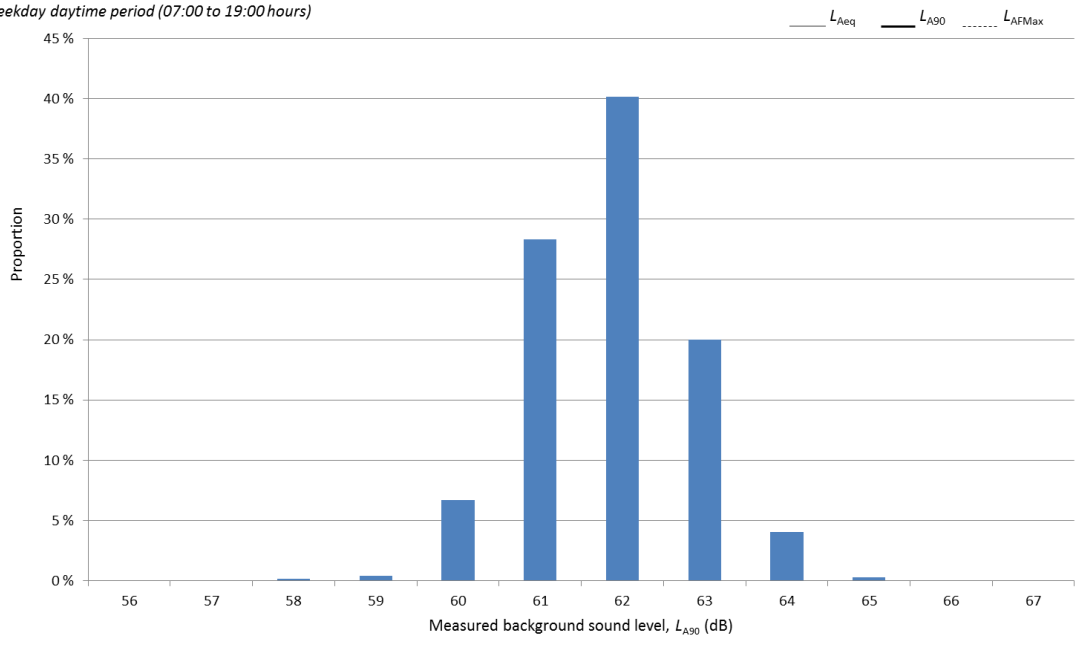
150 Holborn
Statistical analysis of evening background sound level at L2
13 October 2015 to 20 october 2015
Weekend evening period (19:00 to 23:00 hours)



150 Holborn
Statistical analysis of night time background sound level at L2
13 October 2015 to 20 october 2015
Weekend night-time period (23:00 - 07:00 hours)



150 Holborn
Statistical analysis of commercial day time background sound level at L2
13 October 2015 to 20 october 2015
Weekday daytime period (07:00 to 19:00 hours)



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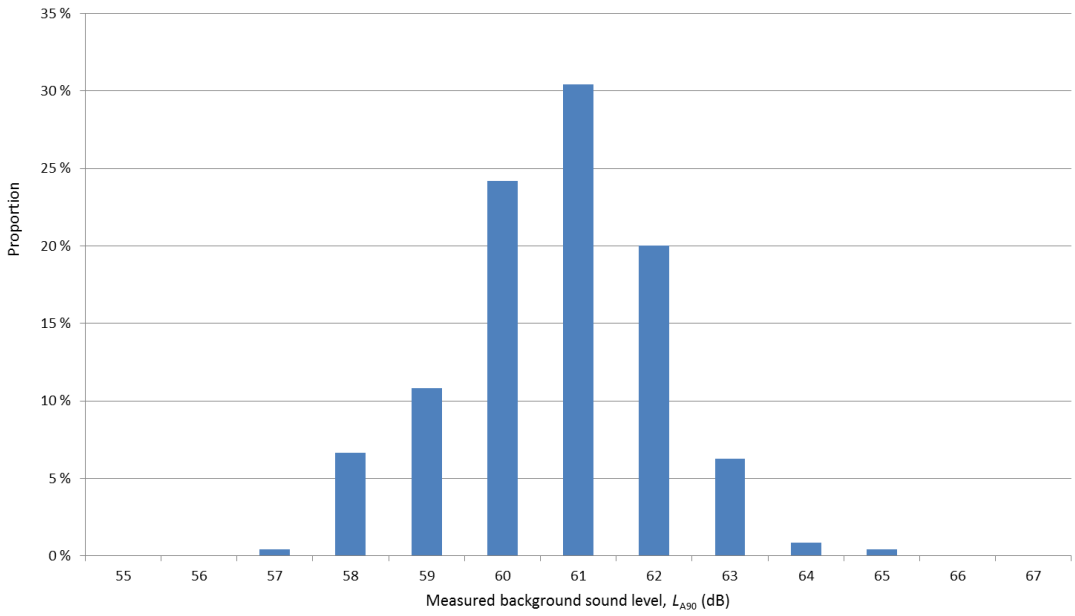
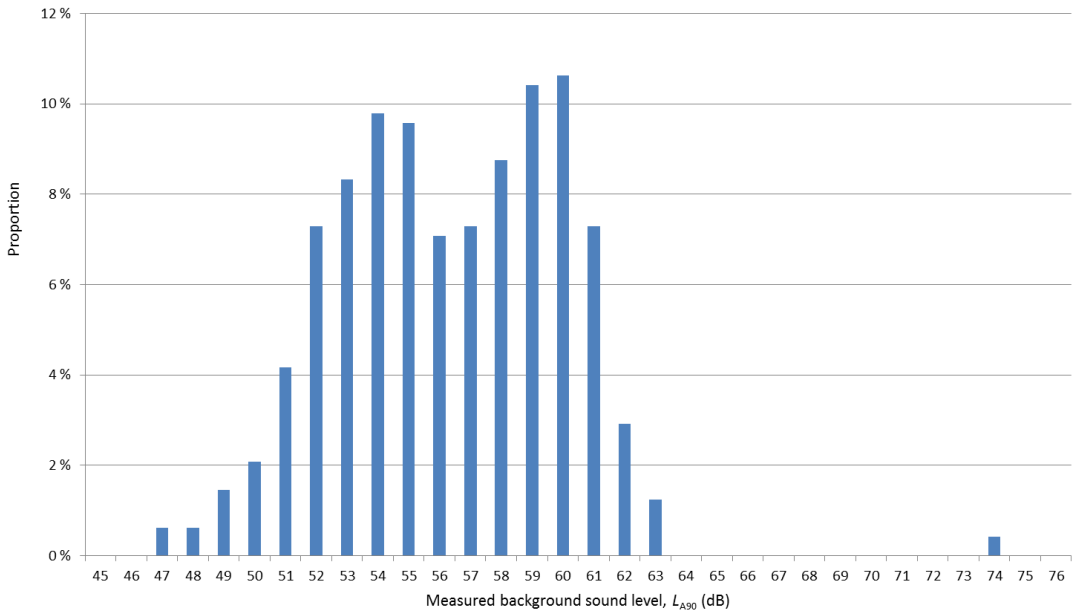
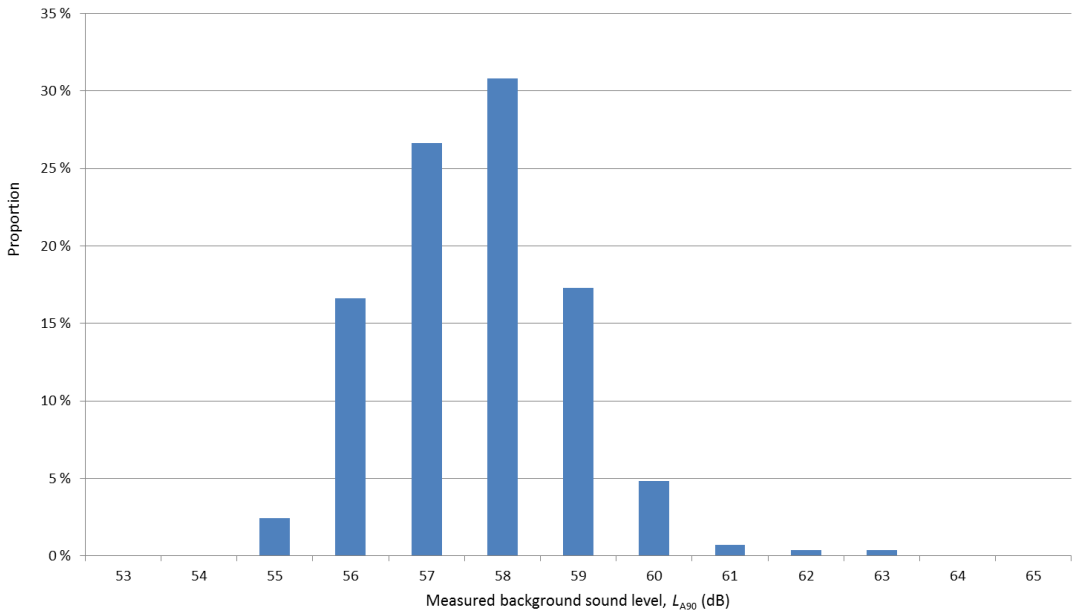
Statistical analysis of evening background sound level at L2
13 October 2015 to 20 october 2015
Weekday evening period (19:00 to 23:00 hours)



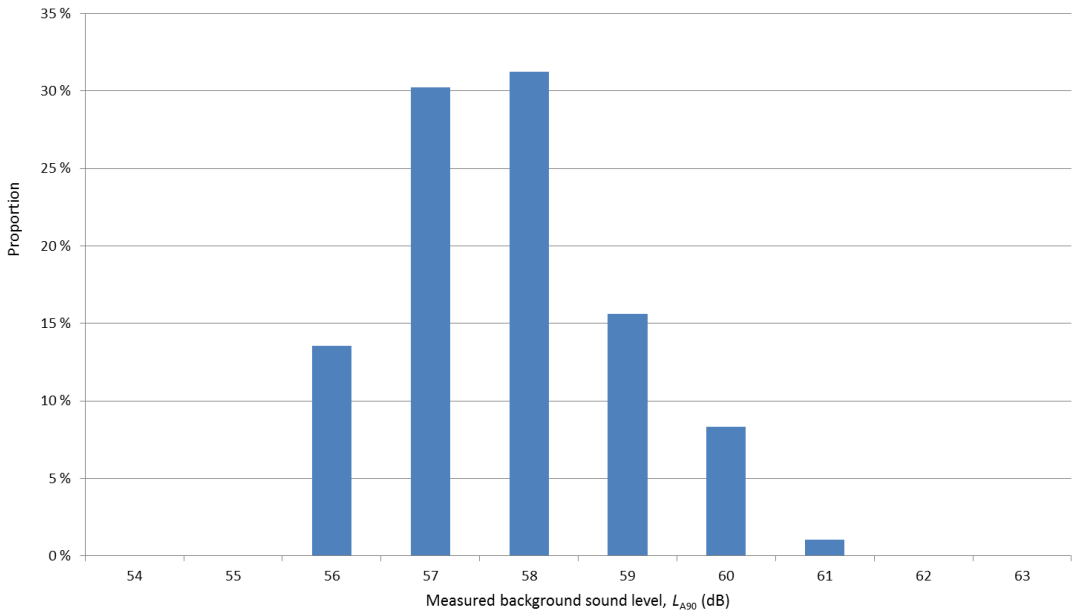
150 Holborn
Statistical analysis of night time background sound level at L2
13 October 2015 to 20 october 2015
Weekday night-time period (23:00 - 07:00 hours)



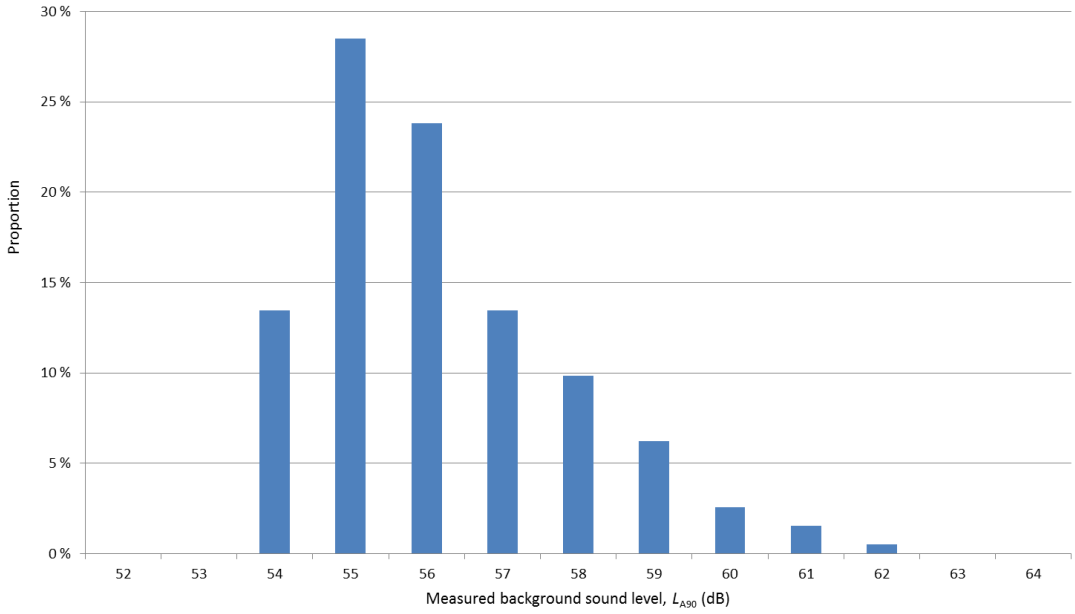
150 Holborn
Statistical analysis of commercial daytime background sound level at L3
15 October 2015 to 20 October 2015
Weekend daytime period (07:00 to 19:00 hours)



150 Holborn
Statistical analysis of evening background sound level at L3
15 October 2015 to 20 October 2015
Weekend evening period (19:00 to 23:00 hours)



150 Holborn
Statistical analysis of night time background sound level at L3
15 October 2015 to 20 October 2015
Weekend night-time period (23:00 - 07:00 hours)



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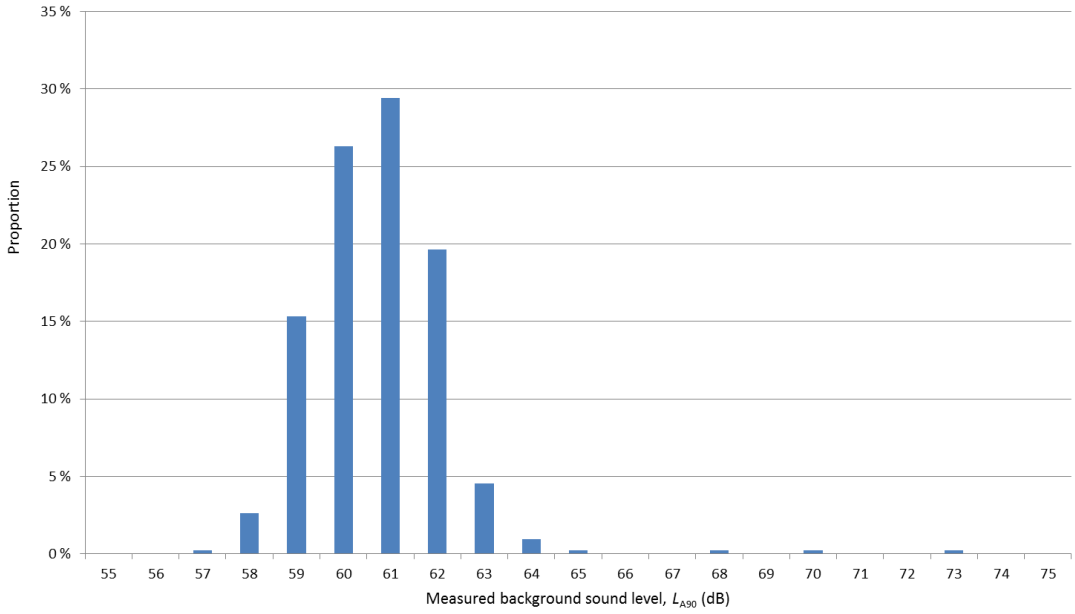
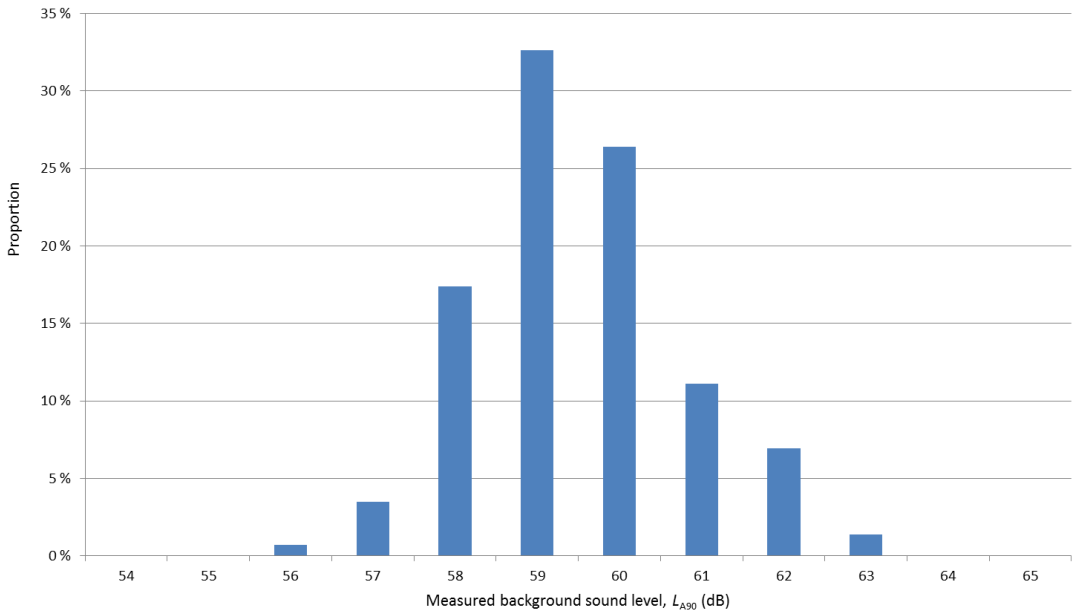
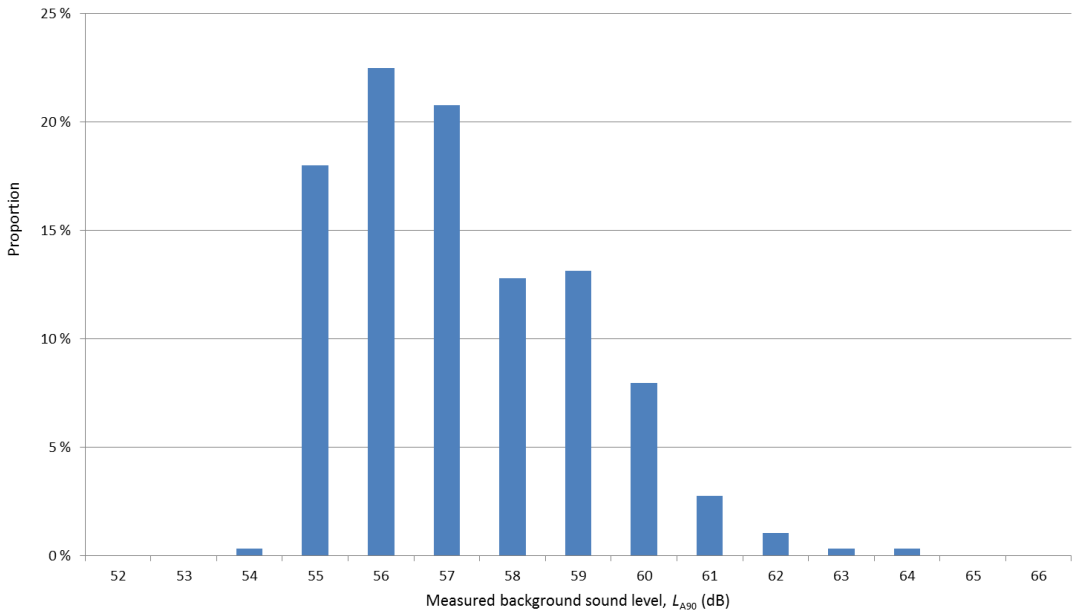
Statistical analysis of commercial day time background sound level at L3
15 October 2015 to 20 October 2015
Weekday daytime period (07:00 to 19:00 hours)



150 Holborn
Statistical analysis of evening background sound level at L3
15 October 2015 to 20 October 2015
Weekday evening period (19:00 to 23:00 hours)



150 Holborn
Statistical analysis of night time background sound level at L3
15 October 2015 to 20 October 2015
Weekday night-time period (23:00 - 07:00 hours)



Appendix B

Vibration survey and assessment

SANDY BROWN

Consultants in Acoustics, Noise & Vibration

15374-R02-B

7 March 2016

150 Holborn

Vibration survey and assessment

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Version	Date	Comments	Author	Reviewer
A	16 Nov 15		Richard Deane	Andrew Long
B	7 Mar 16		Philip Owen	Stephen Stringer

Summary

Sandy Brown Associates LLP (SBA) has been commissioned by DAH Real Estate sarl to provide acoustic advice in relation to the proposed mixed use commercial led development at 150 Holborn.

The proposed development lies close to the existing London Underground Central Line tunnels and as such there is potential for train-induced ground-borne vibration to affect the completed development.

In order to assess the levels of train-induced ground-borne vibration likely to be experienced in the completed development, vibration measurements have been undertaken at eight positions in the existing building.

The results of the survey, which was undertaken on 13 October 2015 and 19 October 2015, indicate that neither the levels of tactile vibration nor re-radiated noise are likely to be such that further vibration mitigation is required.

Contents

1 Introduction

Sandy Brown Associates LLP (SBA) has been commissioned by DAH Real Estate sarl to provide acoustic advice in relation to the proposed development at 150 Holborn.

A vibration survey was performed with objective of assessing the degree to which the proposed development will be affected by tactile vibration (with reference to BS 6472:2008 *Evaluation of Human Exposure to Vibration in Buildings – Part 1: Vibration from sources other than blasting*) and re-radiated noise from train movements along the railway tracks adjacent to the site.

This report presents vibration survey methods, the results of the surveys, and an assessment of tactile vibration and ground-borne noise levels.

2 Site description

2.1 The site and its surroundings

The site location in relation to its surroundings is shown in Figure 1. The site is located at 150 Holborn, with Grays Inn Road to the west and Brooke Street to the east. The site falls into the London Borough of Camden (LBC), with the boundary of the City of London (CoL) being just to the south of Holborn. Chancery Lane tube station lies to the south of the site, servicing trains on the central line of the London Underground.

The site is adjacent to ground floor retail buildings on the south facade, residential to the west and a Grade 2 listed office building to the east.

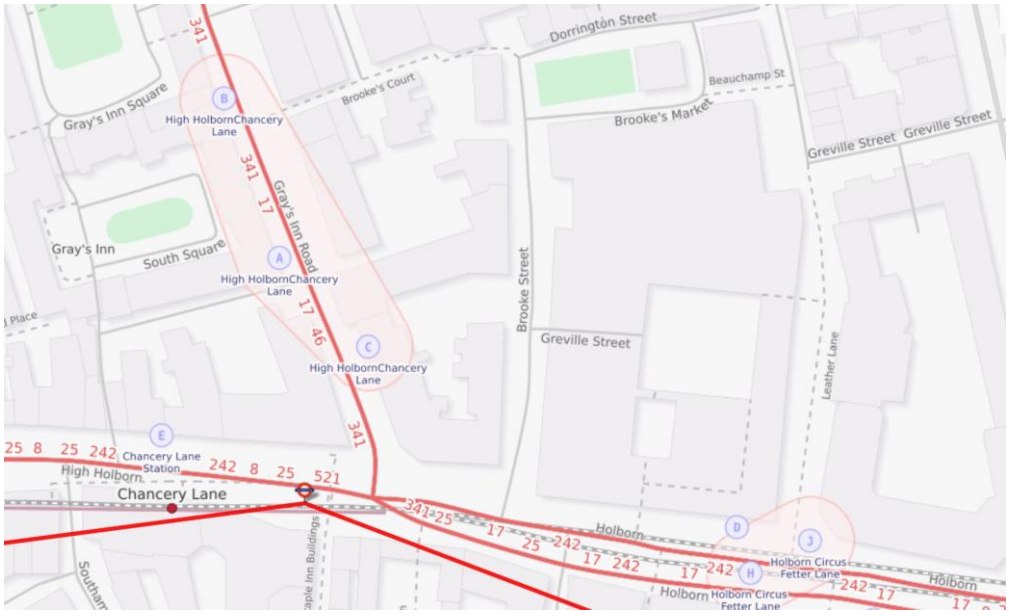


Figure 1 Site map showing the location of the central line to the south

3 Method

Details of the equipment used are provided in Appendix A. Further information on the specific survey method is provided in this section. The vibration survey was undertaken by Philip Owen and Richard Deane.

3.1 Vibration survey method

Vibration measurements were performed at 8 locations in the existing building in order to determine the maximum vibration levels from the passage of trains. The vibration measurement locations are indicated in Figure 2 as positions 1 to 8.

Figure 2 Vibration measurement locations (from top left clockwise: basement, ground floor, second floor, first floor)

Vibration measurements were taken at positions 1-8 on the 13 October, and simultaneous noise and vibration measurements were taken at positions 1-3 on the 19 October.

Measurements taken were post-processed to obtain the vibration dose values (VDV) and the 1/3 octave band slow weighted RMS acceleration. The VDV measurements were processed to establish levels of tactile vibration while the 1/3 octave band slow weighted RMS acceleration values were used to predict the re-radiated L_{ASmax} noise levels.

Vibration measurements were performed at locations 1-4 as, being in the basement and first floor, these positions were considered to be the closest locations to the trains and hence would experience the most vibration. Vibration measurements were performed at locations 6 and 8 to gain an understanding of the variation in the building response to the vibration with height. Vibration measurements performed at locations 5 and 7 are considered to be reasonably representative of the vibration levels likely to be experienced at the proposed residential premises.

The accelerometers were fixed to washers using beeswax, which in turn were fixed to the floor using epoxy resin, away from the room boundaries.

Figure 3 Example of accelerometer set up

All measurements were conducted in three axes as follows:

- X axis - Horizontal vibration
- Y axis - Horizontal vibration perpendicular to X axis
- Z axis - Vertical vibration.

3.1.1 Simultaneous measurements

Simultaneous noise and vibration measurements were performed by Philip Owen at locations 1-3. The measurements were carried out in order to compare predictions of re-radiated noise based on measured vibration with measured re-radiated noise.

For each measurement the microphone was mounted on a tripod approximately 1.5 m above the ground level.

Figure 4 Photograph showing the set up for simultaneous noise and vibration measurements

4 Measurement results

4.1 Vibration measurement results

Graphs displaying the Z axis acceleration measured at positions 1-8 on 13 October can be found in Appendix B.

The VDV measured at positions 1-8 is shown in Table 5 to Table 12 in Appendix C.

4.2 Simultaneous noise measurement results

The octave band L_{Aeq} measured at positions 1 to 3 on 19 October are displayed in Table 13 to Table 15 in Appendix D.

5 Assessment criteria

5.1 Tactile vibration criteria

5.1.1 Standard guidance

Tactile vibration is that which is perceived as mechanical motion. BS 6472-1: 2008 *Guide to Evaluation of Human Exposure to Vibration in Buildings Part 1: Vibration Sources Other Than Blasting* provides procedures for assessing the potential human response to vibration.

Vibration is assessed in terms of the equivalent 'Vibration Dose Value (VDV)'. This relates the level and duration of vibration.

For information, the BS 6472-1: 2008 assessment table is reproduced below:

Table 1 BS 6472-1: 2008 tactile vibration assessment criteria

Vibration dose values ($m/s^{1.75}$) above which might result in various degrees of adverse comment within residential buildings.			
Place	Low probability of adverse comment	Adverse comment possible	Adverse comment probable
Residential buildings 16 hr day	0.2 to 0.4	0.4 to 0.8	0.8 to 1.6
Residential building 8 hr night	0.1 to 0.2	0.2 to 0.4	0.4 to 0.8

Note that offices and workshops, multiplying factors of 2 and 4 respectively should be applied to the above vibration dose value ranges for a 16 hr day. It is important to note that people exhibit wide variations of vibration tolerance. Specific values are dependent upon social and cultural factors, psychological attitudes and expected degree of intrusion.

5.1.2 Local Authority requirements

Table C from Section 3, Camden Development Policies, DP28, as issued by Camden Council, requires that the VDV values shown in Table 2 should not be exceeded.

Table 2 VDV limits for residential and office buildings within Camden Council

	Day and evening (0700-2300)	Night (2300-0700)
Residential	0.2-0.4 VDV $ms^{-1.75}$	0.13 VDV $ms^{-1.75}$
Office	0.4 VDV $ms^{-1.75}$	0.4 VDV $ms^{-1.75}$

5.2 Re-radiated noise criteria

5.2.1 Standard guidance

There is currently no international or British Standard which provides guidance on assessing the impact of ground-borne noise from railways on the occupants of a building. The Association of Noise Consultants (ANC) guidelines '*Measurement and assessment of ground-borne noise and vibration*', 2nd edition published in 2012, is generally used as the basis of assessments such as this.

This document also provides discussion on the relevant research that has been carried out, and a summary of typically adopted criteria.

The most relevant items are set out below:

- The American Public Transit Association (APTA) guidelines recommend criteria of between 30 and 40 dB(A) depending on the density and type of residential properties. They do not define where within a building these apply, or the time response that should be used.
- The Federal Transit Administration (FTA) of the US Department of Transportation, recommends limits for maximum pass-by levels of 35 dB(A) for frequent events (more than 70 events per day) and 43 dB(A) for infrequent events.
- London Underground Limited has studied the relationship between ground-borne noise levels and complaint thresholds. This was used to define a complaint threshold of 40 dB L_{Amax}.
- The ANC guidelines also note that Local Authority guidelines for ground-borne noise were published in London and the South East, and state a limit of 35 dB L_{Amax}.

In all of the above examples, the time constant is not defined, with the exception of the Local Authority guidelines in London and the South East, which is defined as having a fast time weighting. BS ISO 14837-1:2005, however, suggests that ground-borne noise should be quantified using the L_{Amax} parameter with the slow time constant.

It should be noted that most of this research relates to residential accommodation, and is aimed at providing good sleeping / resting conditions.

With regards to offices, *British Council for Office Guide to Specification 2014 (BCO Guide)* states that:

"*Vibration transfer from intermittent sources, such as underground trains, to internal areas should not lead to re-radiated noise levels in occupied cellular offices and meeting rooms of more than 45 dB L_{Amax} or 50 dB L_{Amax} for open plan offices".*

5.2.2 Local Authority requirements

Camden Development Policies, DP28, as issued by Camden Council, states that "*Where dwellings may be affected by ground borne regenerated noise internally from, for example, railways or underground trains within tunnels noise levels within the rooms should not be greater than 35 dB(A)max".*

5.2.3 Client requirements and proposed criteria

An appropriate re-radiated noise criterion will need to be discussed and agreed with the Client and this may require an audio simulation/demonstration of different of re-radiated noise levels to establish what could be considered acceptable within the proposed residences.

The level of structure-borne noise from trains within apartments relates to the perception of quality. Audibility of such noise must take into account the likely level of underlying continuous background noise from sources such as mechanical ventilation, ie the lower this is the more pronounced will noise be from other events such as underground trains.

There is a general tendency towards quieter and quieter apartments (higher performance facades and quieter ventilation equipment) which would naturally lean towards a lower criterion for structure-borne noise from underground trains. Indeed, there are examples of exclusive luxury developments which have been designed to achieve more stringent standards tending towards the inaudibility of noise from underground trains.

However, for the time being and on the basis of the criteria discussed above, a re-radiated noise limit of L_{ASmax} 35 dB is considered suitable for the proposed residences.

Further, the criteria set out in the BCO guide are considered suitable for office spaces subject to agreement with the client.

6 Vibration assessment

6.1 Tactile vibration

BS 6472 states that the assessment should be based on the axis along which the highest VDV is measured. At all measurement locations, the highest VDV was measured on the Z axis.

Published timetables indicate that approximately 60 trains pass by the site per hour. This will result in approximately 960 trains passing on the tracks between 07:00 – 23:00. At night, between 23:00 – 07:00, the number of trains operating along this line is expected to be approximately 480 trains assuming a 24 hour tube service which may be in place in the near future.

Based on the number of trains passing on the tracks between 07:00 – 23:00 and 23:00 – 07:00, the equivalent VDVs over a 16 hour day and an 8 hour night are given in the Table 3.

Table 3 Maximum equivalent Vibration Dose Values

Position	Vibration Dose Value ($m/s^{1.75}$)					
	Day (07:00 – 23:00)			Night (23:00 – 07:00)		
	Horizontal 1	Horizontal 2	Vertical	Horizontal 1	Horizontal 2	Vertical
1	0.00	0.00	0.02	0.00	0.00	0.02
2	0.00	0.00	0.02	0.00	0.00	0.02
3	0.00	0.00	0.01	0.00	0.00	0.01
4	0.00	0.00	0.05	0.00	0.00	0.04
5	0.00	0.00	0.02	0.00	0.00	0.01
6	0.00	0.00	0.02	0.00	0.00	0.01
7	0.00	0.00	0.02	0.00	0.00	0.02
8	0.00	0.00	0.01	0.00	0.00	0.01

By comparing the calculated day and night time vibration dose values in Table 3 with the assessment table given in Section 5.1 of this report, it can be seen that the predicted VDVs during the daytime and night periods are lower than the threshold of the 'low probability of adverse comment' category for both office spaces and residences. As such, tactile vibration due to trains is not considered to be problematic at this site.

6.2 Re-radiated noise

Groundborne noise within the proposed development was predicted using an empirical formula described in '*Guidelines for the Measurement & Assessment of Groundborne Noise and Vibration (2nd Edition)*' published by the Association of Noise Consultants in 2012.

The highest predicted re-radiated noise levels, at each vibration measurements are presented in Table 4 in terms of L_{ASmax}. Also presented are the measured re-radiated noise levels at positions 1-3 for comparison.

Table 4 Summary of predicted and measured re-radiated noise levels

Position	Highest predicted noise level L_{Asmax} (dB)	Highest measured noise level L_{Asmax} (dB)	Dominant axis
1	40	48	Vertical (Z)
2	29	49	Vertical (Z)
3	31	45	Vertical (Z)
4	39	n/a	Vertical (Z)
5	24	n/a	Horizontal (X)
6	29	n/a	Vertical (Z)
7	25	n/a	Vertical (Z)
8	25	n/a	Vertical (Z)

The predicted noise values were found to be lower than those measured. This is expected to be due to reverberant contribution to the noise inside the basement spaces. The spaces in which measurements were taken are large in volume, empty, and unfurnished.

During the vibration measurements, approximately 130 individual train events were observed. The highest predicted L_{ASmax} level based on measurements for all of these events was 40 dB, which was measured in location 1 (basement on Holborn facade).

Of the train passes captured at the location of the proposed office and residential spaces during the survey period, all of the predicted levels are lower than the criteria discussed in Section 5.2.

A significant decrease in predicted re-radiated noise was noted on upper floors with the worst cases being the basement and ground floor Holborn facade.

The vibration acceleration measured at the basement level of the existing concrete frame building was used to approximate the worst case re-radiated noise level which could be experienced on a new building on the site.

The assessment was based on a set of worst case scenario corrections found in section 16/10 of the *Transportation Noise Reference Book.* The assessment indicated that the maximum re-radiated noise levels experienced in the first floor offices would be expected to be L_{ASmax} 44 dBA, with the maximum re-radiated noise levels experienced in the first floor residential spaces expected to be L_{ASmax} 34 dBA. These noise levels are in line with the criteria set out within section 5.2.3 for the respective residential and commercial spaces within the scheme.

It is however likely that the actual L_{ASmax} experienced in the proposed structure would be less, but also the criteria of the client may be more stringent. Therefore, further assessment would be required when a criterion has been decided and a structural design confirmed.

Furthermore, the eventual re-radiated noise within the proposed building may be lower than that set out herein, depending on the proposed structure and foundations etc. A further, more detailed assessment would be required to quantify this.

7 Conclusion

A vibration survey has been carried out at 150 Holborn in order to assess tactile vibration and re-radiated noise associated with train-induced groundborne vibration affecting the proposed development.

Based on the requirements of Camden Council, proposed re-radiated noise criteria and on the results of the survey, neither tactile vibration nor re-radiated noise levels are deemed to be such that vibration mitigation measures are required for the proposed development.

Appendix A

Survey details

Equipment

The VDV and 1/3 octave band RMS acceleration measurements were carried out using a Rion DA20 vibration level meter and a Brüel & Kjær 2250 sound level meter, respectively.

The calibration details for the equipment used during the survey are provided in Table A1.

Table A1 Equipment calibration data

Equipment description	Type/serial number	Manufacturer	Calibration expiry	Calibration certification number
Sound level meter	2250/2693829	Bruel & Kjaer	30 Jan 16	07524/07525
Microphone	4189/2689268	Bruel & Kjaer	30 Jan 16	07524/07525
Pre-amp	ZC0032/12061	Bruel & Kjaer	30 Jan 16	07524/07525
Calibrator	4231/3001923	Bruel & Kjaer	30 Jan 16	07518
Data Recorder	DA-20/10870889	Rion	7 Sep 17	TCRT15/1252
Accelerometer	PV-87/33827	Rion	8 Sep 17	1509496
Accelerometer	PV-87/33828	Rion	8 Sep 17	1509497
Accelerometer	PV-87/33829	Rion	8 Sep 17	1509498
Vibration Calibrator	AT01/3015	AP Technology	8 Sep 17	1509495

Calibration of the meters used for the tests is traceable to national standards. The calibration certificates for the sound level meter(s) used in this survey are available upon request.

The sound and vibration level meters and the respective measurement chains were calibrated at the beginning and end of the measurements using their respective sound level calibrators. No significant calibration deviation occurred.

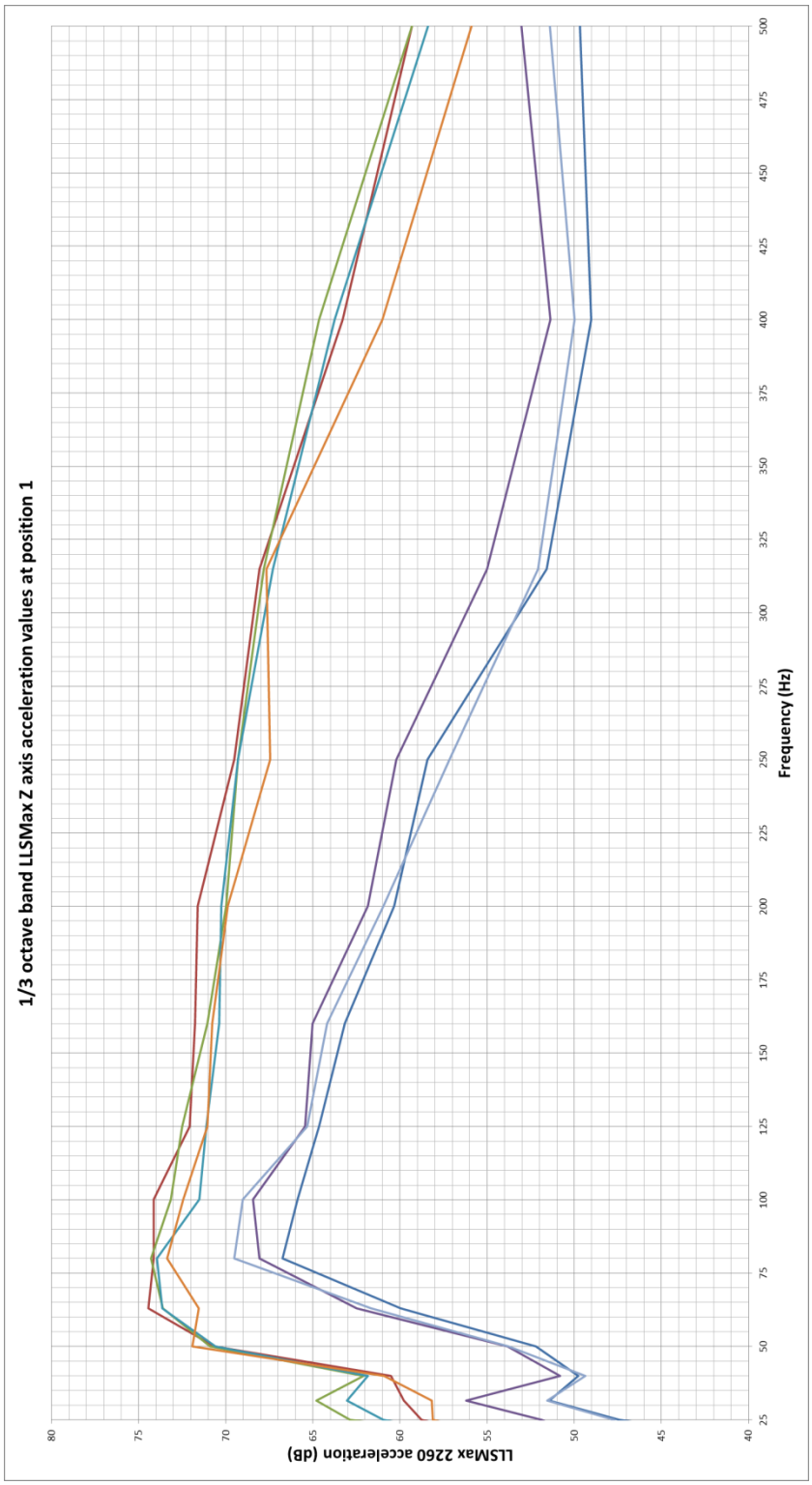
Vibration indices

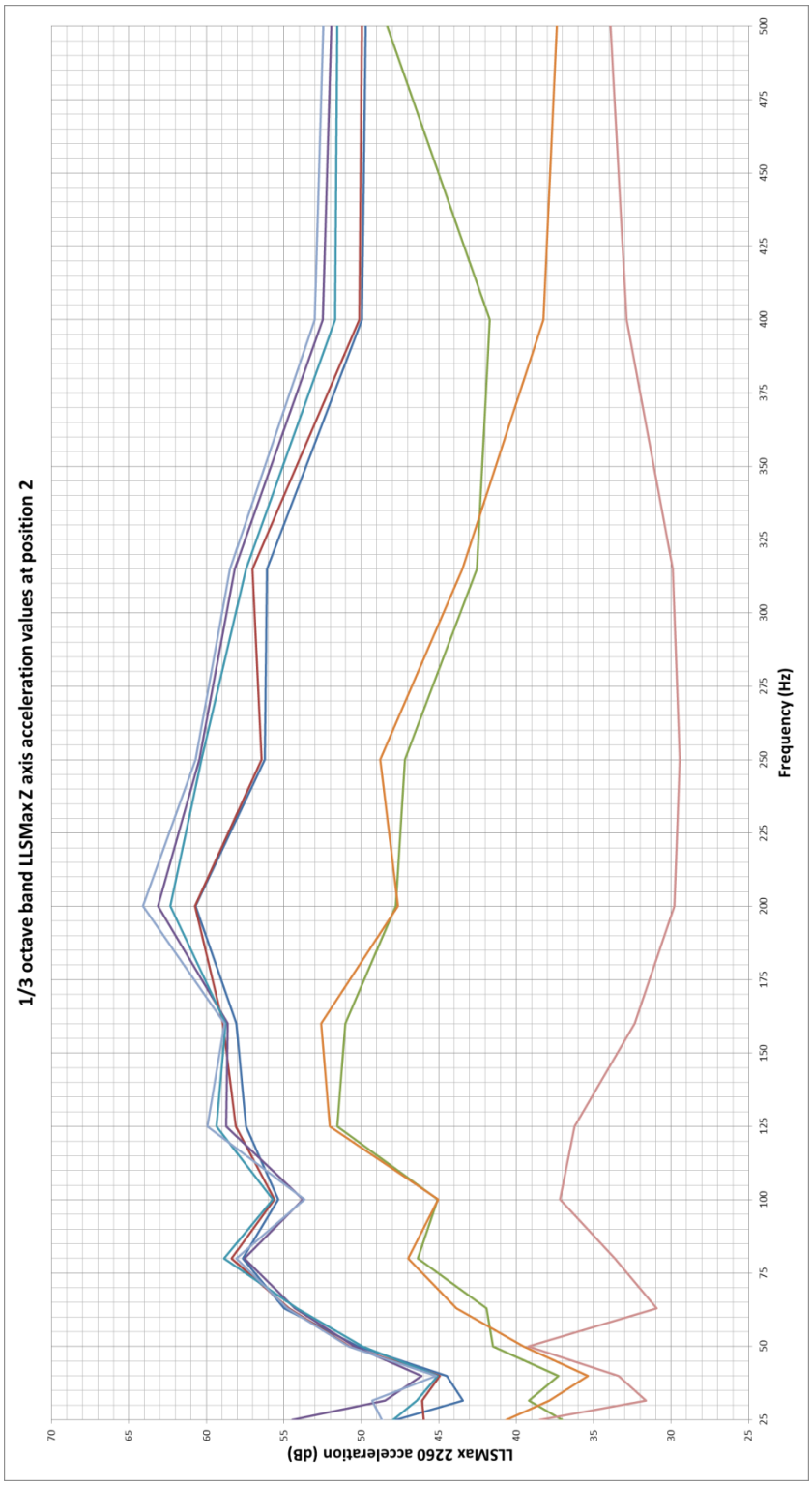
For each measurement period a number of parameters were recorded. The most relevant of these are described below:

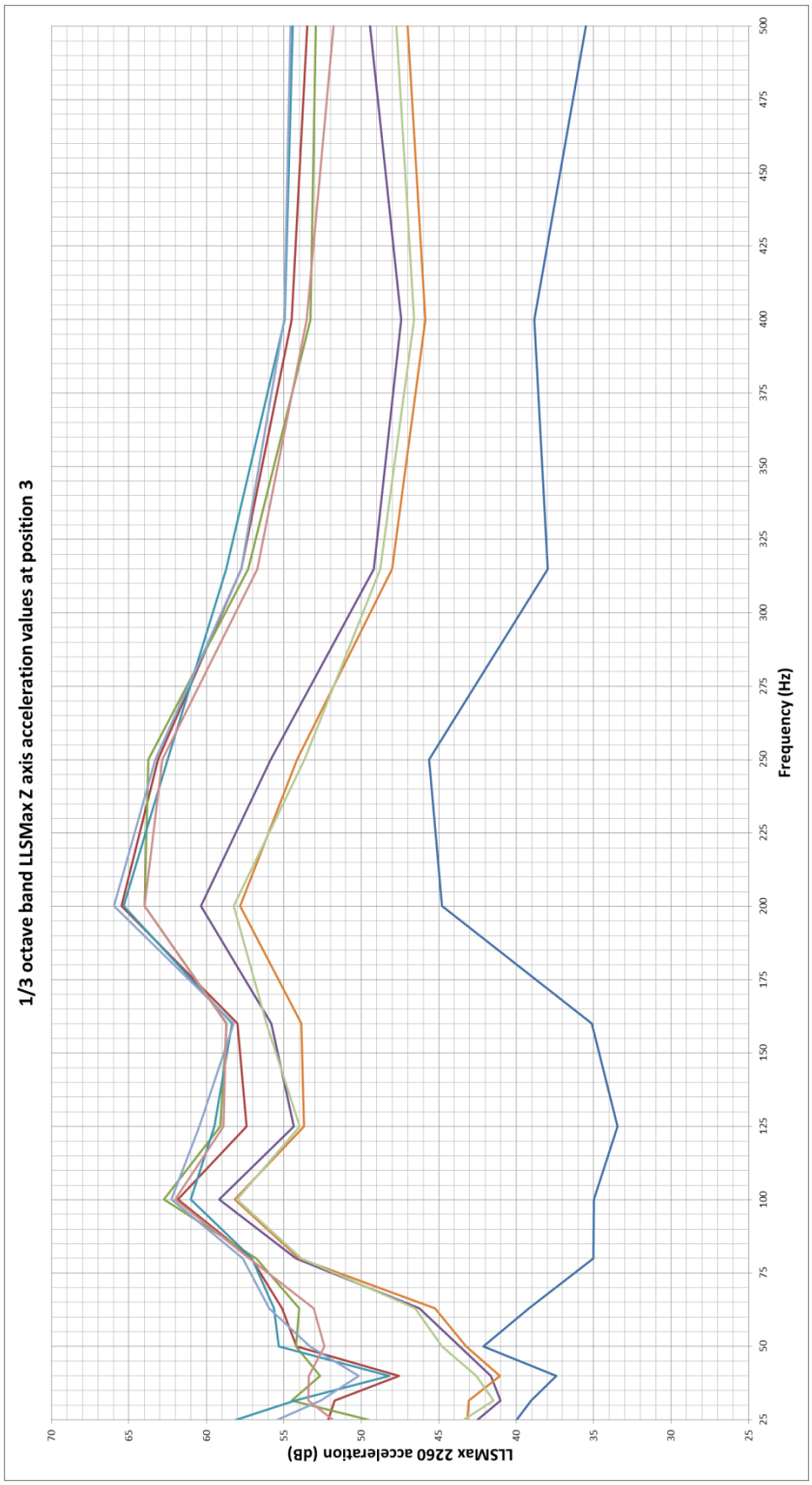
- The vibration dose value (VDV) in each of three axes with the appropriate frequency weightings (as defined in BS 6472-1:2008).
- The maximum RMS acceleration levels in each of three axes in one-third-octave bands, measured using the ‘slow response’ exponential time weighting.

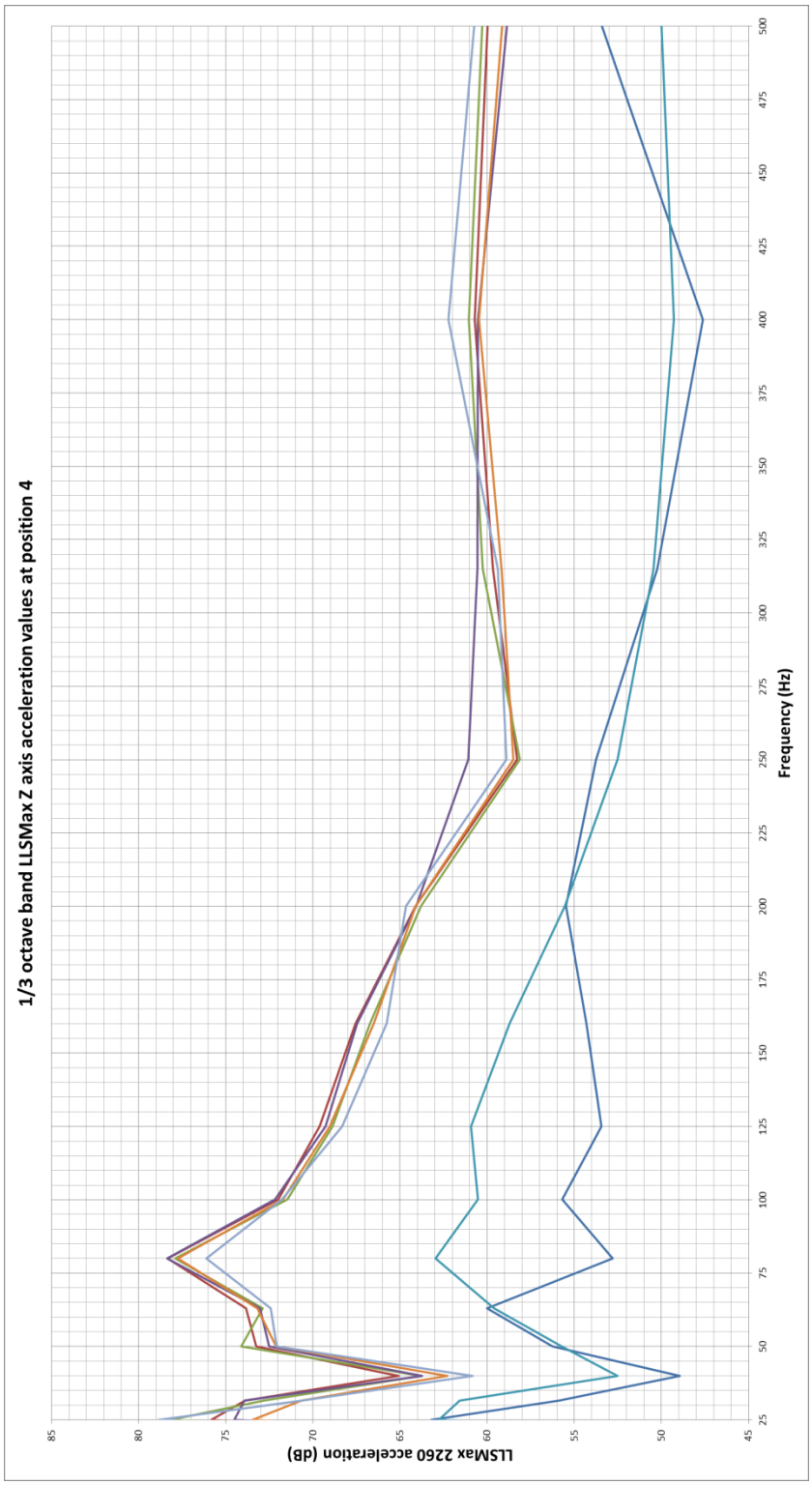
Appendix B

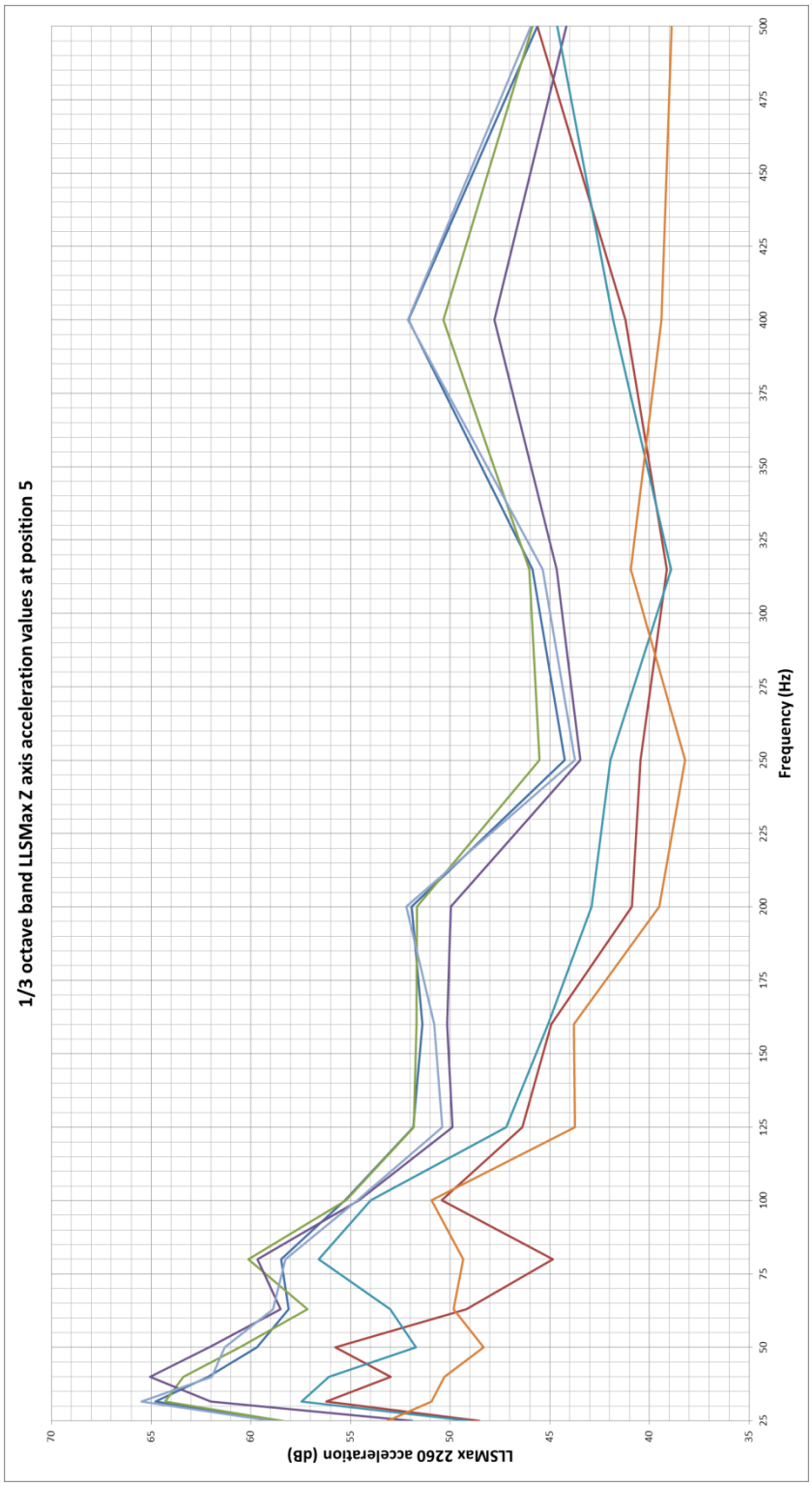
Acceleration measured at positions 1-8

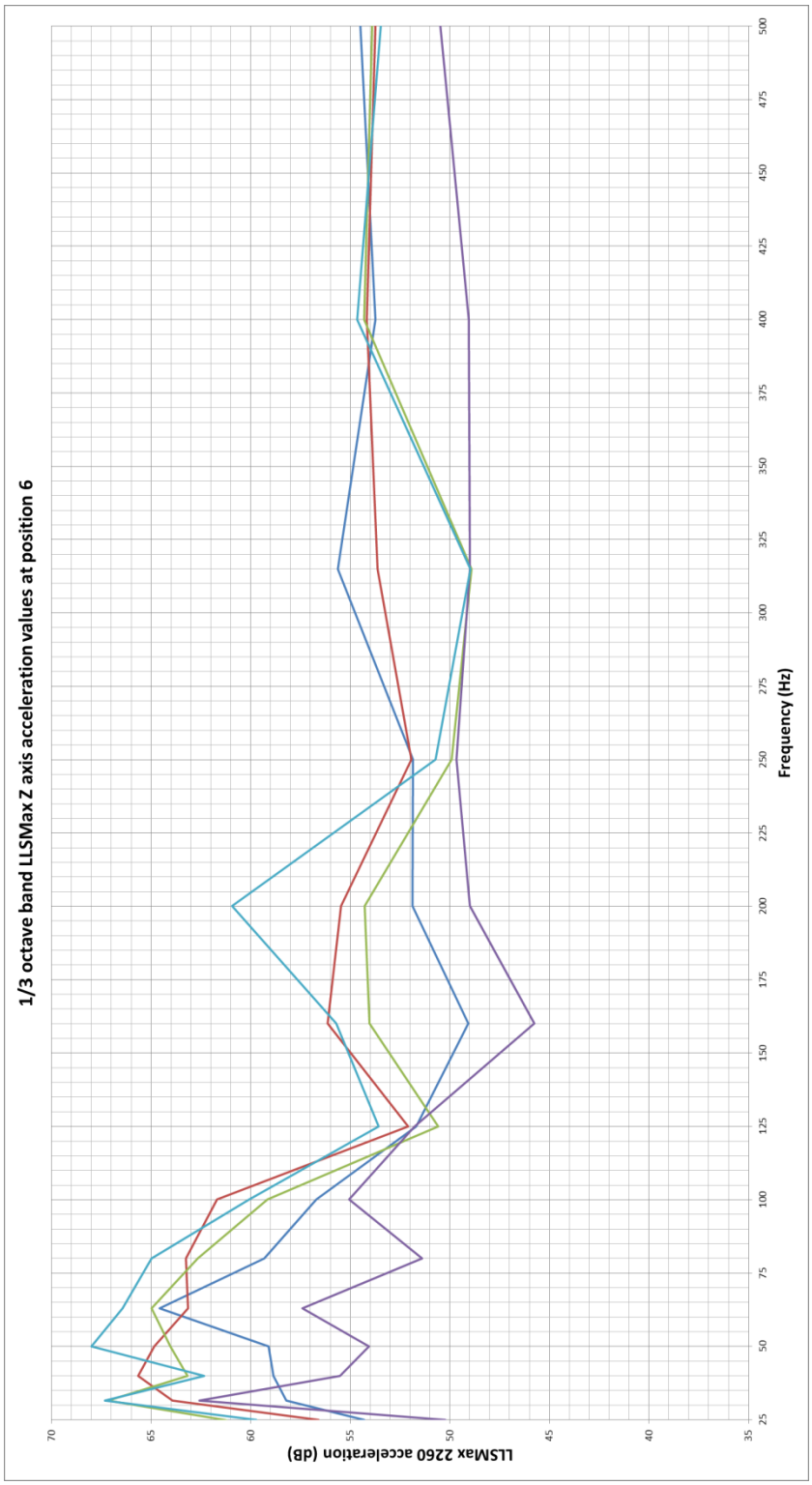

1/3 octave band LLSMax Z axis acceleration values at position 1
LLSMax 2260 acceleration (dB)
Frequency (Hz)
80
75
70
65
60
55
50
45
40
25
50
75
100
125
150
175
200
225
250
275
300
325
350
375
400
425
450
475
500

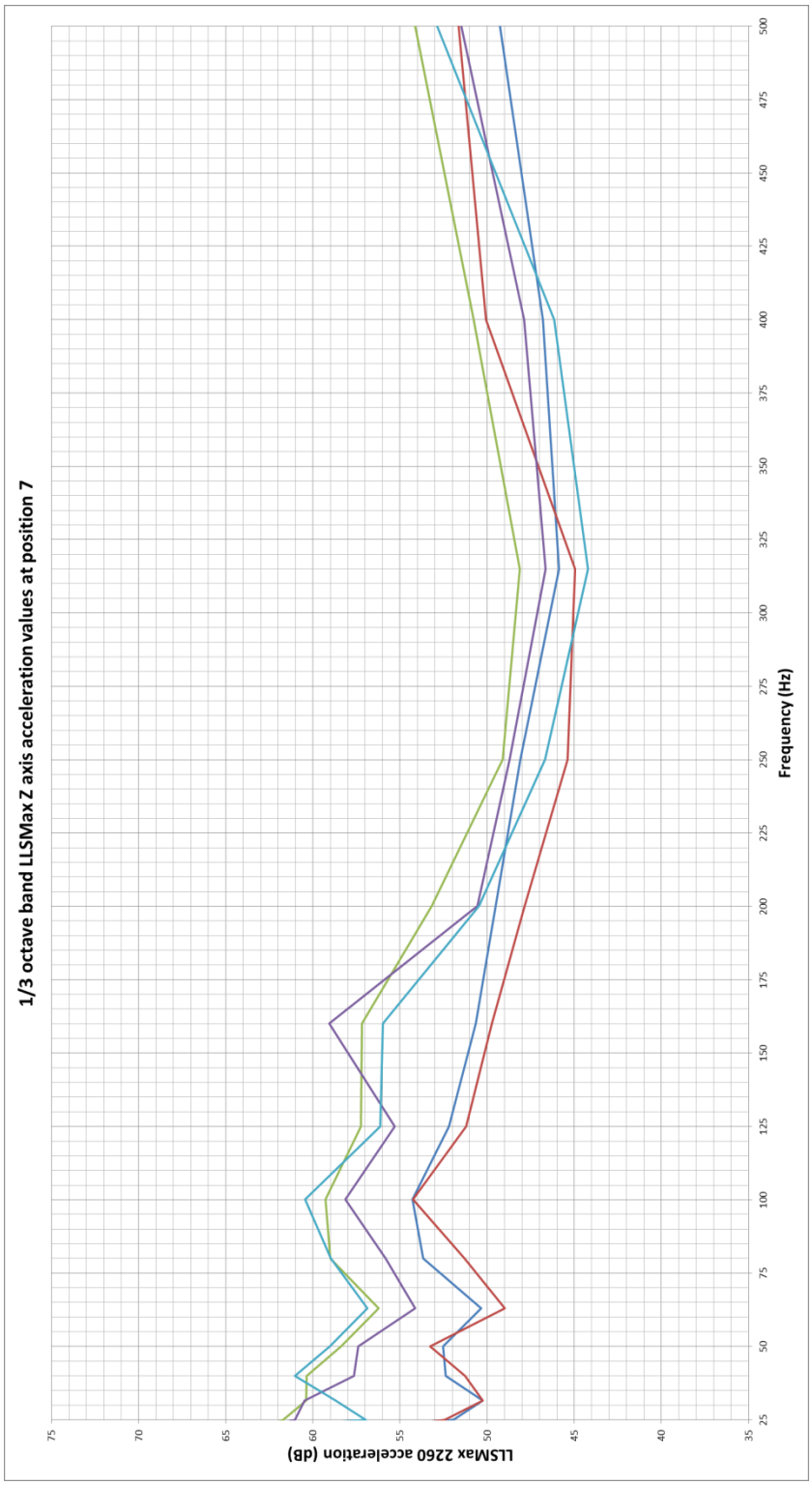

1/3 octave band LLSMax Z axis acceleration values at position 2
LLSMax 2260 acceleration (dB)
Frequency (Hz)
70
65
60
55
50
45
40
35
30
25
500
475
450
425
400
375
350
325
300
275
250
225
200
175
150
125
100
75
50
25

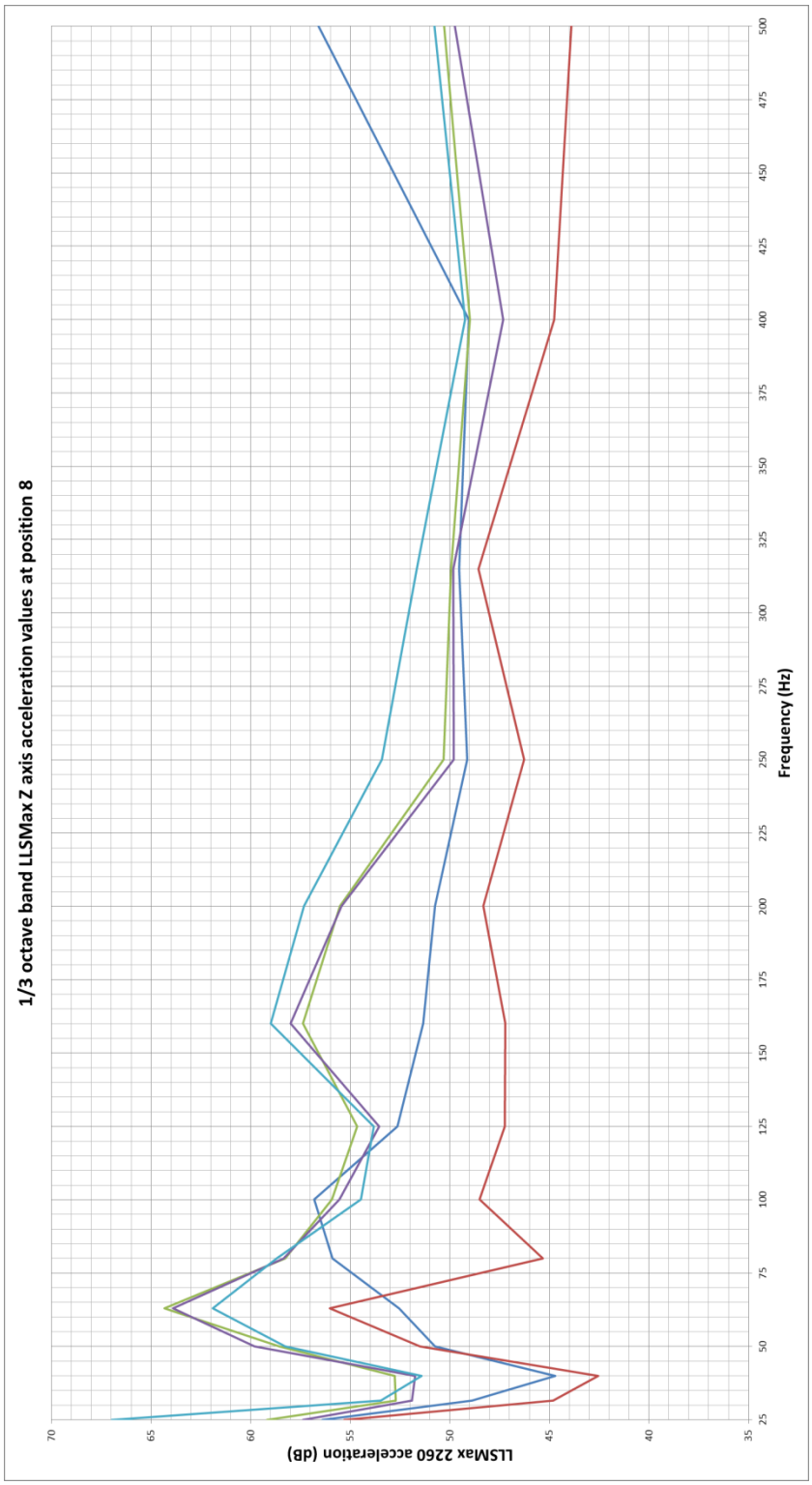

1/3 octave band LLSMax Z axis acceleration values at position 3
LLSMax 2260 acceleration (dB)
Frequency (Hz)
70
65
60
55
50
45
40
35
30
25
25
50
75
100
125
150
175
200
225
250
275
300
325
350
375
400
425
450
475
500


1/3 octave band LLSMax Z axis acceleration values at position 4
LLSMax 2260 acceleration (dB)
Frequency (Hz)
85
80
75
70
65
60
55
50
45
25
50
75
100
125
150
175
200
225
250
275
300
325
350
375
400
425
450
475
500


1/3 octave band LLSMax Z axis acceleration values at position 5
LLSMax 2260 acceleration (dB)
Frequency (Hz)
70
65
60
55
50
45
40
35
25
50
75
100
125
150
175
200
225
250
275
300
325
350
375
400
425
450
475
500


1/3 octave band LLSMax Z axis acceleration values at position 6
LLSMax 2260 acceleration (dB)
Frequency (Hz)
70
65
60
55
50
45
40
35
25
50
75
100
125
150
175
200
225
250
275
300
325
350
375
400
425
450
475
500


1/3 octave band LLSMax Z axis acceleration values at position 7
LLSMax 2260 acceleration (dB)
Frequency (Hz)
75
70
65
60
55
50
45
40
35
25
50
75
100
125
150
175
200
225
250
275
300
325
350
375
400
425
450
475
500


1/3 octave band LLSMax Z axis acceleration values at position 8
LLSMax 2260 acceleration (dB)
Frequency (Hz)
70
65
60
55
50
45
40
35
25
50
75
100
125
150
175
200
225
250
275
300
325
350
375
400
425
450
475
500

Appendix C

VDV measured at positions 1-8

Table 5 VDV measured at position 1

Position	VDV ($m/s^{1.75}$)		
	X axis	Y axis	Z axis
1	0.00046	0.00026	0.00185
1	0.00053	0.00026	0.00152
1	0.00053	0.00027	0.00381
1	0.00054	0.00029	0.00161
1	0.00063	0.00033	0.00157
1	0.00066	0.00035	0.00372
1	0.00069	0.00037	0.00156
1	0.00066	0.00038	0.00427
1	0.00069	0.00038	0.00382
1	0.00069	0.00039	0.00139
1	0.00072	0.00042	0.00426
1	0.00079	0.00043	0.00449
1	0.00075	0.00043	0.00147
1	0.00078	0.00044	0.00411
1	0.00080	0.00044	0.00393
1	0.00083	0.00047	0.00164

Table 6 VDV measured at position 2

Position	VDV ($m/s^{1.75}$)		
	X axis	Y axis	Z axis
2	0.00086	0.00049	0.00435
2	0.00075	0.00041	0.00074
2	0.00075	0.00041	0.00035
2	0.00074	0.00040	0.00072
2	0.00074	0.00040	0.00037
2	0.00074	0.00040	0.00092
2	0.00073	0.00039	0.00080
2	0.00073	0.00040	0.00038
2	0.00073	0.00039	0.00080
2	0.00072	0.00039	0.00036
2	0.00073	0.00040	0.00031

Table 7 VDV measured at position 3

Position	VDV ($m/s^{1.75}$)		
	X axis	Y axis	Z axis
3	0.00073	0.00040	0.00072
3	0.00069	0.00038	0.00107
3	0.00071	0.00039	0.00103
3	0.00069	0.00038	0.00067
3	0.00070	0.00039	0.00120
3	0.00068	0.00039	0.00091
3	0.00068	0.00038	0.00168
3	0.00068	0.00037	0.00120
3	0.00068	0.00038	0.00089
3	0.00068	0.00036	0.00095
3	0.00069	0.00038	0.00056

Table 8 VDV measured at position 4

Position	VDV ($m/s^{1.75}$)		
	X axis	Y axis	Z axis
4	0.00069	0.00040	0.00232
4	0.00072	0.00044	0.00894
4	0.00069	0.00040	0.00185
4	0.00075	0.00046	0.00991
4	0.00073	0.00046	0.00805
4	0.00070	0.00040	0.00231
4	0.00075	0.00044	0.00723
4	0.00072	0.00043	0.00115
4	0.00075	0.00045	0.00936

Table 9 VDV measured at position 5

Position	VDV ($m/s^{1.75}$)		
	X axis	Y axis	Z axis
5	0.00084	0.00047	0.00209
5	0.00084	0.00050	0.00233
5	0.00082	0.00050	0.00344
5	0.00084	0.00052	0.00241
5	0.00084	0.00049	0.00275
5	0.00081	0.00050	0.00125
5	0.00085	0.00049	0.00159
5	0.00086	0.00051	0.00163
5	0.00085	0.00054	0.00243

Table 10 VDV measured at position 6

Position	VDV ($m/s^{1.75}$)		
	X axis	Y axis	Z axis
6	0.00089	0.00051	0.00215
6	0.00085	0.00052	0.00299
6	0.00089	0.00051	0.00194
6	0.00089	0.00052	0.00350
6	0.00087	0.00051	0.00317
6	0.00088	0.00053	0.00333

Table 11 VDV measured at position 7

Position	VDV ($m/s^{1.75}$)		
	X axis	Y axis	Z axis
7	0.00083	0.00053	0.00235
7	0.00085	0.00052	0.00191
7	0.00087	0.00054	0.00356
7	0.00084	0.00050	0.00166
7	0.00088	0.00057	0.00403
7	0.00083	0.00052	0.00364
7	0.00088	0.00058	0.00244
7	0.00079	0.00050	0.00158
7	0.00078	0.00052	0.00388
7	0.00080	0.00049	0.00334

Table 12 VDV measured at position 8

Position	VDV ($m/s^{1.75}$)		
	X axis	Y axis	Z axis
8	0.00080	0.00049	0.00131
8	0.00076	0.00048	0.00087
8	0.00076	0.00047	0.00168
8	0.00075	0.00046	0.00163
8	0.00075	0.00046	0.00180
8	0.00077	0.00051	0.00264

Appendix D

Simultaneous noise measurements

Table 13 Simultaneous noise measurement results at position 1

Position	Noise level (dB) at octave band centre frequency (Hz)								LASmax
	63	125	250	500	1k	2k	4k	8k	
1	54	40	33	30	23	15	12	10	37
1	51	40	34	31	28	22	22	19	38
1	52	47	36	31	17	12	12	10	40
1	55	47	37	33	24	15	11	9	41
1	61	55	44	39	28	17	20	22	47
1	62	55	44	35	24	15	14	10	48
1	56	47	36	30	21	15	16	12	42
1	62	55	44	37	27	21	17	11	48
1	55	48	35	33	24	15	10	9	41
1	50	42	37	32	21	17	13	11	38
1	55	48	35	31	24	16	15	12	41
1	61	55	44	36	24	15	15	13	48
1	62	56	47	40	36	23	14	10	48

Table 14 Simultaneous noise measurement results at position 2

Position	Noise level (dB) at octave band centre frequency (Hz)								L_{ASmax}
	63	125	250	500	1k	2k	4k	8k	
2	46	41	36	33	27	20	13	10	39
2	57	53	40	30	24	19	11	9	45
2	48	45	40	38	31	19	16	12	43
2	58	53	42	33	30	20	14	11	45
2	51	47	43	33	26	19	14	11	43
2	58	54	47	40	36	23	13	14	49

Table 15 Simultaneous noise measurement results at position 3

Position	Noise level (dB) at octave band centre frequency (Hz)								L_{ASmax}
	63	125	250	500	1k	2k	4k	8k	
3	48	44	36	30	25	24	20	13	39
3	54	49	40	28	27	21	19	14	43
3	55	48	46	35	30	25	18	11	45
3	57	50	41	31	20	13	14	10	42
3	46	44	34	27	21	13	10	9	36
3	55	49	41	33	26	16	10	9	43
3	47	44	34	24	20	16	13	10	37
3	55	48	44	36	28	21	12	10	45
3	40	36	32	26	21	19	11	8	34