St Clare Business Park
Hampton Hill
Richmond

Train Induced Vibration and Assessment Report

24902/VAR2 Rev1

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For:

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0	31/5/2022	-	Andrew Fermer Director BSc(Hons), MIOA	Simon Hancock Director BEng(Hons), CEng, MIMechE, MCIBSE, FIOA
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Appendix A – Vibration Terminology

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1.0 Introduction

A mixed use scheme is proposed on behalf of Notting Hill Home Ownership Ltd. at the site of St. Clare Business Park in Hampton Hill, Richmond. Demolition of existing buildings and erection of 1no. mixed use building between three and five storeys plus basement in height, comprising 98no. residential flats (Class C3) and 1,172sq.m of commercial floorspace (Class E); 1no. three storey building comprising 893sq.m of commercial floorspace (Class E); 14no. residential houses (Class C3); and, associated access, external landscaping and car parking.

The site is adjacent to a railway line Hann Tucker Associates have therefore been commissioned to establish the current incident train induced vibration levels and to subsequently use the results of the survey alongside the proposed construction details in order to predict the likely train induced vibration and re-radiated noise levels in the development.

2.0 Objectives

To establish, by means of site measurements, the magnitude and frequency distribution of ground borne vibration resulting from the movement of surface trains.

To present suitable train induced vibration and re-radiated noise criteria.

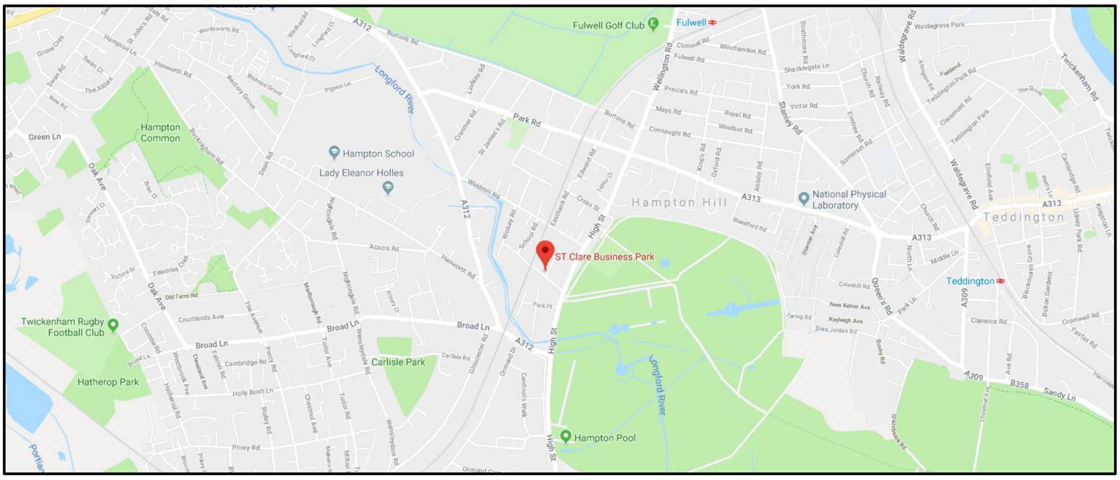
To assess the likely levels of vibration and re-radiated noise based on the results of the vibration survey and the proposed substructures and superstructures.

To recommend any potential amelioration measures if deemed necessary.

3.0 Site Description

3.1 Location

The site is located in Hampton Hill, Richmond, as shown in the Location Map below.



Location Map (© Google 2018)

The site falls within the jurisdiction of The London Borough of Richmond upon Thames.

3.2 Description

The site is bounded by a railway line to the west, by properties on Windmill Road to the north, properties on High Street to the east, and properties on Holly Road to the south. The railway line comprises two tracks, one for trains travelling north to south and vice versa. The line runs between Hampton and Fulwell railway stations. During the periods that we were on site there were 1 to 2 trains on each track per hour. Subjectively the trains were travelling at medium or medium/slow speeds and the track/rolling stock interaction appeared relatively smooth, based on the sound of the train passbys.

The site is shown in the Site Plan below.

Site Plan (© Google 2018)

The site currently comprises mainly small commercial units and car parking. Some of the units were operational and others were vacant.

Subjectively the dominant noise sources were trains from the adjacent railway line (approximately 2 to 4 trains per hour), bird song, light noise from commercial premises still operational (conversation, hand tools), and an occasional distant rumble assumed to be due to air traffic from Heathrow airport approximately 7km to the north-west.

4.0 Vibration Survey

4.1 Instrumentation

The following instrumentation was used for the survey and subsequent analysis:

- 2No. Dytran Accelerometers
- 01dB – Sinus Symphonie PCMCIA Hardware Interface
- 01dB – dBTrig V4.704 vibration Acquisition Software
- 01dB – dBTrait V4.704 Vibration Analysis Software
- B&K 2260 Sound Level Meter
- Microsoft Windows Based Laptop Computer

The 01dB hardware and software connects to two accelerometers via a four channel USB unit. The system can record data in ‘real-time’ to a computer allowing simultaneous analysis in both the time and frequency domains.

The analysis chain was calibrated prior to the measurements to enable subsequent analysis.

The vibration measurements were undertaken with the accelerometer attached via a strong magnet to steel washers glued to the ground surfaces using an Araldite 2 part glue.

4.2 Procedure

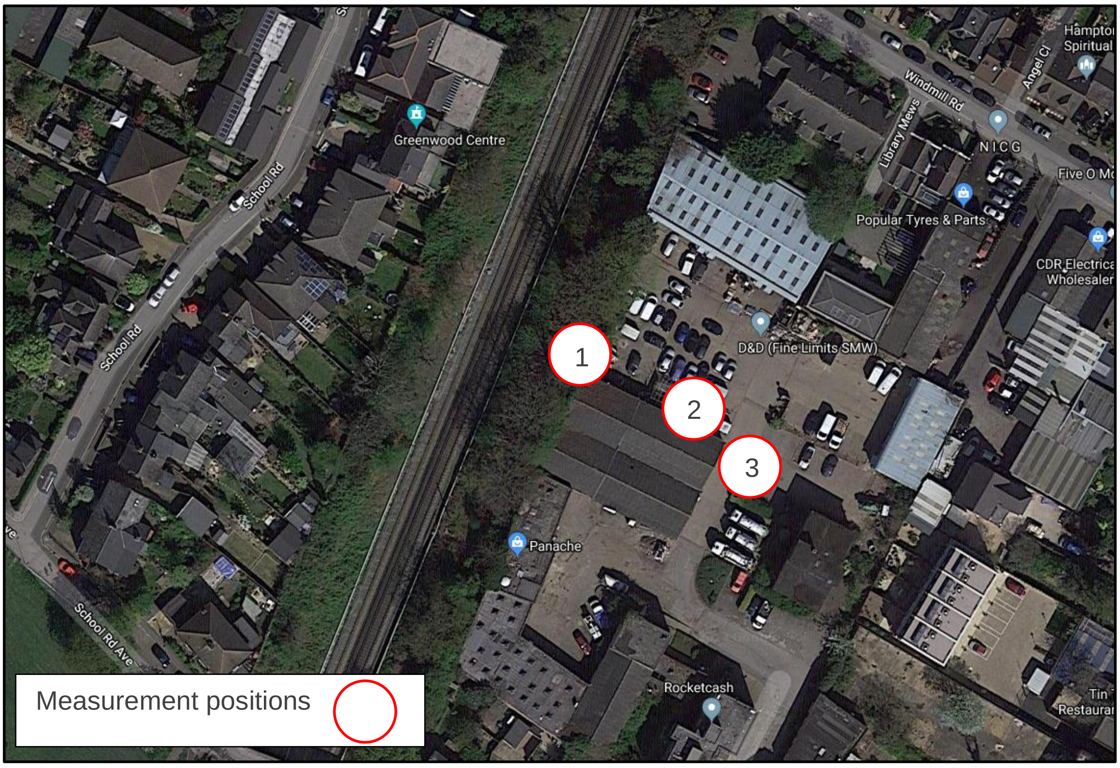
A vibration survey was undertaken between approximately 12:30 hours and 14:00 hours on 18 January 2018 and between approximately 10:00 hours and 11:30 hours on 19 January 2018.

Vibration measurements were undertaken in order to establish the prevailing vibration levels due to train movements.

The measurement positions are described below.

Position	Description
1	The accelerometer was located approximately 3m from the site boundary, deemed to be representative of the closest buildings in the proposed scheme, approximately 18m from the nearest railway track. The accelerometer was mounted to the hardstanding currently used by the car garage for parking cars.
2	The accelerometer was located approximately 23m from the site boundary, approximately 38m from the nearest railway track. The accelerometer was mounted to the hardstanding currently used by the car garage for parking cars.
3	The accelerometer was located approximately 38m from the site boundary, approximately 53m from the nearest railway track. The accelerometer was mounted to the hardstanding currently used for car parking serving the various commercial units.

These positions, shown on the site plan below, were selected to measure both the worst case vibration levels experienced by the site, and also how these levels vary with position across the site.



Plan Showing Unmanned Measurement Positions (© Google 2018)

5.0 Survey Results

Typical measured vibration levels for different directions of train passbys from the measurement positions are presented on Graphs 24902/G1 to 24902/G3 enclosed.

The vertical, W_b weighted peak acceleration ranged from 0.019-0.026m/s^2 at Position 1 to 0.005-0.006m/s^2 at Position 3.

Based on the measured 5minute VDVs during individual train passbys, and the number of passbys noted in Section 7, the calculated daytime and night-time VDVs are as follows:

Location	Period	Calculated V.D.V. (m/s$^{1.75}$)
Position 1	Daytime (07:00 – 23:00)	0.04
	Night-Time (23:00 – 07:00)	0.02
Position 3	Daytime (07:00 – 23:00)	0.01
	Night-Time (23:00 – 07:00)	0.01

6.0 Criteria

6.1 Vibration

6.1.1 British Standards

British Standard BS 6472: 2008 "*Guide to Evaluation of Human Exposure to Vibration in Buildings*" advises that intermittent vibration events should not be judged based on perception alone but using the corresponding vibration dose value over a long period.

BS6472:2008 advises that "the VDV defines a relationship that yields a consistent assessment of continuous, intermittent, occasional and impulsive vibration and correlates well with subjective response" and also "the VDV is much more strongly influenced by vibration magnitude than by duration. A doubling of halving of the vibration magnitude is equivalent to an increase or decrease of exposure duration by a factor of sixteen."

The table below details the Vibration Dose Values ($m/s^{1.75}$) above which various degrees of adverse comment may be expected in Residential Buildings.

Time Period	Low probability of adverse comment	Adverse comment possible	Adverse comment probable
Daytime (07:00– 23:00)	0.2 to 0.4	0.4 to 0.8	0.8 to 1.6
Night-time(23:00–07:00)	0.1 to 0.2	0.2 to 0.4	0.4 to 0.8

The table below details the Vibration Dose Values ($m/s^{1.75}$) above which various degrees of adverse comment may be expected in Office Buildings.

Time Period	Low Probability of adverse comment	Adverse comment possible	Adverse comment probable
Daytime (07:00– 23:00)	0.4	0.8	1.6

The perception threshold for continuous whole-body vibration varies widely among individuals. Approximately half a typical population, when standing or seated, can perceive a vertical weighted peak acceleration of 0.015 m/s^2. The weighting used is W_b. A quarter of the population would perceive a vibration of 0.010m/s^2 peak, but the least sensitive quarter would only be able to detect a vibration of 0.020m/s^2 peak or more. Perception thresholds are slightly higher for vibration duration of less than about 1 second.

Please refer to Appendix A for an explanation of the vibration terminology used in this report.

6.1.2 Local Authority

The site falls under the jurisdiction of London Borough of Richmond. Their criteria are contained within their SPD document 'Development Control for Noise Generating and Noise Sensitive Development' as follows:

*"The Vibration Dose Values ($ms^{-1.75}$) (VDV) should be calculated and assessed from the measured acceleration levels in accordance with BS6472-1:2008. For residential development, the VDV after any required mitigation should not exceed the levels in **Table 6** below (taken from Table 1 of BS 6472-1:2008)."*

07:00 – 23:00 16 hour day	23:00 – 07:00
< 0.2 $m.s^{-1.75}$	< 0.1 $m.s^{-1.75}$

6.2 Ground-borne Noise

6.2.1 General Guidance

Currently no British Standards exist which recommend a method by which to assess intermittent ground-borne or structure-borne noise, such as that induced by trains.

Whilst there is no widely accepted method of evaluation of groundborne noise, there is some consensus that for levels at and above 50dBA L_{smax} during daytime, there is likely to be significant adverse reaction. For residential situations the L_{smax} noise levels for which there is likely to be little adverse comment can be taken as around 30dBA during the daytime and around 25dBA during night-time. Some local authorities recommend in their planning policies a level of 35dBA L_{max}.

The Association of Noise Consultants (ANC) - "Measurement and Assessment of Groundborne Noise & Vibration" (Third Edition), presents the following impact classification tables for residential and non-residential receptors, which have been drawn from major railway projects in the UK and Ireland, e.g. Crossrail, the Jubilee Line, Dublin Area Rapid Transit (DART) and HS1.

Groundborne Noise Impact Criteria for Residential Receptors presented in ANC "Measurement and Assessment of Groundborne Noise & Vibration"		
Impact Classification	***Groundborne Noise Level dBA L_{smax} (measured indoors, near the centre of any dwelling room on the ground floor)***	
Negligible	*<35*	*Not significant*
Low	*35-39*	
Medium	*40-44*	*Significant impact*
High	*45-49*	
Very High	*>49*	

Groundborne Noise Impact Criteria for Non-Residential Receptors presented in ANC "Measurement and Assessment of Groundborne Noise & Vibration"	
Building	***Significant Impact Threshold dBA L_{smax}***
Theatres/large auditoria and concert halls	*25*
Sound recording/broadcast studios	*30*
Places of meeting for religious worship/courts/lecture theatres/museums/small auditoria or halls	*35*
Offices/schools/colleges/hospitals/hotel/libraries	*40*
Factories/warehouses	*50*

Ground-borne noise is of greatest concern when it is the dominant noise, and also when the source cannot be seen, as in the case of trains in a tunnel. Criteria for ground-borne noise are therefore generally intended to apply to sources such as underground trains.

However the railway line affecting this site is a surface line. It is generally accepted that people are more tolerant of noise from sources which can be seen. Furthermore, where sources are visible, airborne noise intrusion through the façade in most cases masks the ground-borne noise which is re-radiated simultaneously.

6.2.2 Local Authority

The document 'London Boroughs of Hillingdon, Hounslow, and Richmond upon Thames Development Control for Noise Generating and Noise Sensitive Development April 2016' contains the following:

"Re-radiated noise, as a result of vibration from adjacent railways and other sources, shall not exceed 35 dB L_{Amax}(slow) within habitable residential rooms. Where it is predicted that noise from this source will exceed 35dB L_{Amax}(slow), proposals to mitigate re-radiated noise to

acceptable levels shall be submitted to and approved in writing by the LPA. However, due to the high cost of mitigating vibration effects, this should be subject to early discussion with the LPA."

In our opinion, and with reference to Section 6.2.1 above, the above criterion is probably intended to apply to re-radiated noise from underground trains and it would be excessively stringent to apply it in this situation.

6.2.3 Commercial

The British Council for Offices 'Guide to Specification 2019' states:

Guidance on ground-borne noise and vibration can be found in BS6472-1: 2008 and ANC Guidelines "Measurement and Assessment of Ground-borne Noise & Vibration". In addition, it is suggested that train induced vibration should not result in re-radiated noise levels of more than the following:

Cellular Offices:	40 dB $L_{AmaN(slow)}$
Meeting Rooms:	40 GB $L_{Amax(slow)}$
Open Plan Offices:	45 dB $L_{AmaN(slow)}$

7.0 Train Movements

The following table presents our estimates of the number of train passes for daytime (07:00 hours to 23:00 hours) and night-time (23:00 hours to 07:00 hours) periods. These predictions are based upon the national rail train timetables.

Daytime (07:00 – 23:00)	Night-Time (23:00 – 07:00)
73	9

Note: The Vibration Dose Value parameter is mainly dictated by the magnitude of the individual train passbys, and is relatively insensitive to the number of train events.

8.0 Building Response

The building development superstructure will modify the surveyed vibration levels, superstructures often amplifying foundation vibration levels. Our analyses assumes the following:

- Empirically researched floor amplification factors as given within *"A Prediction for Rail Transportation Ground-borne Noise and Vibration"* (Ref 1) and *"Handbook for Urban Noise and Vibration Control"* (Ref 2).
- The maximum recorded vibration levels for different train passbys shall be used.
- Measurements were made on hard standing for car parking.
- The proposed commercial and apartment buildings are to have piled foundations, a reinforced concrete frame and concrete floor slabs, and the houses closest to the train tracks are to have small diameter piles, load bearing masonry walls and timber floors.

9.0 Predicted Levels Of Vibration And Re-Radiated Noise

9.1 Vibration Levels

Based on the maximum recorded vibration levels we have calculated the predicted vibration levels within the proposed worst case house and worst case apartment, in the worst affected noise sensitive floor of each. Using the results detailed in Section 7.0 and our predicted vibration levels based on empirical coupling losses and amplification factors, the following approximate future V.D.V.'s have been predicted.

Location	Period	Predicted V.D.V. ($m/s^{1.75}$)
Worst Case Apartment	Daytime (07:00 – 23:00)	0.04
	Night-Time (23:00 – 07:00)	0.03
Worse Case House	Daytime (07:00 – 23:00)	0.09
	Night-Time (23:00 – 07:00)	0.05

Please note these predicted vibration levels are approximate.

9.2 Re-radiated Noise Levels

Based on the maximum recorded vibration levels we have calculated the predicted approximate re-radiated noise levels within the proposed worst case apartments, houses and commercial units at the worst affected noise sensitive floor.

Our analysis indicates the following approximate re-radiated (L_{smax}) noise levels, based on the predicted vibration levels due to the worst case measured train passbys and the proposed substructure and superstructure constructions. Medium floor amplification factors have been used for the apartments and commercial units, due to the proposed concrete floor slabs, and high amplification factors have been used for the houses due to the proposed timber floors. The proposed location of the commercial units is further from the railway line than the residential, and therefore predicted levels are presented at Positions 2 and 3 only.

Location	**Level (dB L_{smax})**		
	Apartment	House	Commercial
Position 1	33	39	-
Position 2	25	31	28
Position 3	16	22	19

Please note these predicted re-radiated noise levels are approximate.

Noise levels will decay slightly with height. A reasonable estimate is to subtract 1dB per floor.

10.0 Discussion Of Results

10.1 Vibration

10.1.1 Surveyed

The magnitude of the vibration of different train passbys varied between the near and far tracks and between different trains on each track. Factors include speed and weight of trains as well as the condition of the rolling stock (i.e. rough wheels).

Whilst tactile vibration was not clearly perceived by the engineer on site, with reference to BS6472:2008 the highest measured W_b weighted vertical vibration levels are likely to be perceivable in areas of the development close to the train line. However, the calculated Vibration Dose Values (VDVs) were well below the Local Authority criteria.

10.1.2 Predicted

The predicted VDVs in both the closest proposed houses and apartments to the train line comply with the criteria set out in Section 6.1.

10.2 Predicted Noise

Re-radiated noise levels in the closest apartments to the train line are predicted to be audible but, with reference to Section 6.2.1, the assessed impact is ‘Low’.

Re-radiated noise levels in the houses are predicted to be higher due to the lightweight floors and differences in foundation types. With reference to Section 6.2.1, the impact of noise levels in houses closest to the railway line is assessed as being at the upper end of the ‘Low’ category.

Re-radiated noise levels in the closest commercial units to the train line are predicted to be just audible but below the BCO criteria presented in Section 6.2.3, noting that there is generally around 2dB difference between fast and slow time weightings for train passbys.

Noise levels are reduced with distance from the railway line. Re-radiated noise levels across the majority of the site are predicted to be less than described above.

It is also worth noting that the number of train passbys is relatively low; generally around 4 per hour and ceasing during late night/early morning.

11.0 Conclusions

A vibration survey has been undertaken to establish the existing levels of train induced vibration across the proposed development site.

The survey results have subsequently been used to predict the likely levels of train induced noise and vibration, based upon our understanding of the proposed scheme.

The results of our assessment indicate that train induced vibration is likely to be perceptible in areas of the development closest to the train line, but should be below the VDV criteria set out by the Local Authority and should be therefore deemed acceptable.

Re-radiated noise levels in the closest apartments to the train line are predicted to be audible but the assessed impact is ‘Low’.

Re-radiated noise levels in the houses are predicted to be higher due to the lightweight floors and differences in foundation types. The impact of noise levels in houses closest to the railway line is assessed as being at the upper end of the ‘Low’ category.

Re-radiated noise levels in the closest commercial units to the train line are predicted to be just audible but below the BCO criteria.

The number of train passbys is relatively low; generally around 4 per hour, ceasing during late night/early morning.

Generally, we would recommend that measures are taken to minimise amplification of vibration levels by the use of heavy, stiff constructions. We would advise against the use of lightweight wide span constructions as these are inherently prone to significant vibration amplification.

St Clare Business Park

References

"A Prediction Procedure for Rail Transportation Ground-borne Noise and Vibration" James Turner Nelson and High Saurenman Transportation Research Record 1143.

"Handbook of Urban Rail Noise and Vibration Control" Saurenman, Nelson, Wilson US Department of Commerce National Technical Information Services – February 1982.

"Measurement and Assessment of Groundborne Noise and Vibration", The Association of Noise Consultants. ISBN 0-9539516-1-8

Appendix A

Vibration Units

The vibratory motion of a surface can be described by either:

(a) displacement (m),

(b) velocity (m/s), or

(c) acceleration (m/s^2).

Furthermore the vibration magnitude can be quantified in several ways:

peak to peak : This value gives the <u>total</u> excursion of the oscillation about the zero datum. The unit is often used where the vibratory displacement of a component is critical for maximum stress or mechanical clearance calculations.

peak : This value gives the maximum excursion of the oscillation above or below the zero datum. This value is useful for indicating the level of short duration shocks.

r.m.s : This value gives the root mean square of the time history over a specific time interval (time constant). This value is useful for indicating the energy content of the vibration.

dB : Decibel quantities are often encountered. A reference level of 10^{-6} m/s^2 r.m.s is typically used for acceleration.

<u>Vibration Dose Value</u> (V.D.V) ($m/s^{1.75}$)

This value assesses both the magnitude of vibration and its duration. Where possible the vibration dose value should be determined over the full exposure to vibration. It is often estimated from the frequency weighted r.m.s value of the acceleration and its duration and is then referred to as e.V.D.V.

Appendix B

dB	:	Decibel - Used as a measurement of sound pressure level. It is the logarithmic ratio of the noise being assessed to a standard reference level.
dBA	:	The human ear is more susceptible to mid-frequency noise than the high and low frequencies. To take account of this when measuring noise, the 'A' weighting scale is used so that the measured noise corresponds roughly to the overall level of noise that is discerned by the average human. It is also possible to calculate the 'A' weighted noise level by applying certain corrections to an un-weighted spectrum. The measured or calculated 'A' weighted noise level is known as the dBA level. Because of being a logarithmic scale noise levels in dBA do not have a linear relationship to each other. For similar noises, a change in noise level of 10dBA represents a doubling or halving of subjective loudness. A change of 3dBA is just perceptible.
L_{max}	:	L_{max} is the maximum sound pressure level recorded over the period stated. L_{max} is sometimes used in assessing environmental noise where occasional loud noises occur, which may have little effect on the L_{eq} noise level.
L_{smax}	:	L_{smax} is the maximum sound pressure level recorded over the period stated where the meter has a slow response (1 second) as opposed to a fast response which is usually set to 0.125 seconds.