

Charles Street

Train Induced Vibration Assessment Report



Charles Street Manchester

Train Induced Vibration Assessment Report

31020/VAR1

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For:
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Document Control

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1	05/12/2023	Updated following team co-ordination and latest plan drawings.		
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Appendix A – Vibration Terminology

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1.0 Introduction

The site, which is located on Charles Street and York Street, is being considered for residential development. The proposals are for the full planning permission for the erection of 15-storey purpose-built student accommodation building, including site preparation works, works over the public highway and associated works.

The site is located close to a raised trainline between Manchester Oxford Road and Manchester Piccadilly train stations and maybe subject to vibration impacts occurring from train pass bys.

Hann Tucker Associates have therefore been commissioned to establish the current train induced vibration levels incident on site. These measurements are used to subsequently predict the likely train induced vibration and re-radiated noise levels in the proposed 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 overground trains.

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

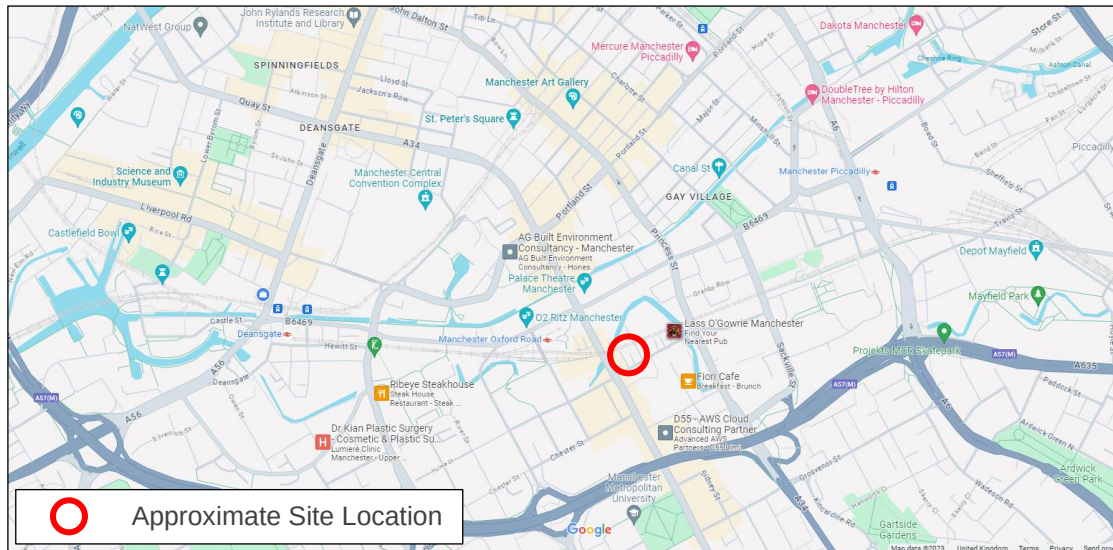
To assess the likely levels of vibration and re-radiated noise based on the results of the vibration survey and the proposed substructures and superstructures.

To recommend any potential amelioration measures if deemed necessary.

3.0 Site Description

3.1 Location

The site is located in Manchester city centre on an area of land located at the junction of Charles Street and York Street. The site falls under the jurisdiction of Manchester City Council and the location is shown in the Location Map below.



Location Map (Map Data © 2023 Google)

3.2 Description

The site is bound by Charles Street to the south, York Street to the west, and the rail line running on the viaduct to the north between Manchester Oxford Road and Manchester Piccadilly train stations. The site is adjacent to Bracken House (residential) to the east, a nursery to the east located within Bracken House, Circle Square (residential) to the south, and The Maldron Hotel to the west.

There is a small MOT car garage located under the arches of the railway line viaduct, approximately 5m north of the site boundary. There are a number of late night entertainment venues located east of the site location, Yes Bar is approximately 45m east, Joshua Brooks and FAC251 are both approximately 95m east of the site location.

The site and the surrounding notable premises are shown in the Site Plan below.



4.0 Vibration Survey

4.1 Instrumentation

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

- 2No. Dytran Accelerometers
- 01dB –dB4 Hardware Interface
- 01dB – dBTrig Vibration Acquisition Software
- 01dB – dBTrait Vibration Analysis Software
- Microsoft Windows Based Laptop Computer

The 01dB hardware connects two accelerometers via a multi-channel USB interface to the laptop computer. The system can record data in real-time to a laptop 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 accelerometers attached to the surfaces using magnetic mounting plates fixed to the ground.



4.2 Procedure

A vibration survey was undertaken on Wednesday 11th October 2023 between approximately 15:00 hours and 17:00 hours.

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

The measurement positions are described below.

Position	Description
V1	At the approximate red line boundary of the site, approximately 6m from the viaduct of the train line.
V2	At the approximate location of the boundary of the proposed new building, approximately 8m from the viaduct of the train line.

5.0 Proposed Criteria

5.1 Tactile Vibration

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 ($\text{m/s}^{1.75}$) 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 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 0.010 m/s^2 peak, but the least sensitive quarter would only be able to detect a vibration of 0.020 m/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.

5.2 Re-radiated Noise

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

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

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_{max} (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	



Re-radiated 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 re-radiated noise are therefore generally intended to apply to sources such as underground trains. Furthermore, where sources are visible, airborne noise intrusion through the façade in most cases masks there-radiated noise which is radiated simultaneously.

A criterion of 35dBA(L_{Smax}) is usually considered suitable for a residential development affected by underground trains. This equates to train movement being audible but not to an extent likely to cause significant adverse comments.

Where bedroom façades are likely to be exposed to relatively high levels of train airborne noise, it could be considered reasonable to apply the same criteria for both re-radiated and airborne noise. For airborne noise intrusion, higher noise levels are generally considered acceptable, of around 45dBA L_{Amax} in the case of residential buildings - corresponding to a low probability of sleep disturbance according to the general consensus of research into this field.

As such, for this scheme we would suggest re-radiated noise be assessed to ideally not exceed L_{ASmax} 40-45 dB.

Please refer to Appendix B for an explanation of the acoustic terminology used in this report.

6.0 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 historic train pass by data obtained from Raildar.com.

Train Type/Description	Daytime (07:00 – 23:00)	Night-Time (23:00 – 07:00)
Passenger	330	45
Freight	12	6

The overground trains typically comprised passenger services of 6-10 carriage trains, there were a selection of intercity trains that had 10-12 carriages, some travelled at greater/slower speed, a single freight trains pass-by was witnessed whilst on site and it is understood that number of these are scheduled to pass during the daytime and night-time.



7.0 Building Response

The building development superstructure will modify the surveyed vibration levels, superstructures often amplifying foundation vibration levels. Our analysis 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 pass-bys shall be used.
- Existing site construction is ground bearing.
- The proposed building structure will be concrete.

8.0 Survey Results

Typical measured vibration levels for different lines, directions, number of carriages, weight, speeds (this should be altered to reflect your measurements) of train pass-bys from the measurement positions are presented on Vibration Graphs 31020/VG1-VG2 enclosed.

9.0 Predicted Levels of Vibration and Re-radiated Noise

9.1 Vibration Levels

Based on the maximum recorded vibration levels we have calculated predicted VDV levels within the proposed development at the worst affected noise sensitive floor. Predictions are made using the measurement data, the estimated train movement frequency detailed in Section 7.0 and medium amplification factors based on the proposed building structure. The following table presents approximate predicted VDV levels based on our understanding of the proposed development.

Period	Location	VDV ($\text{m/s}^{1.75}$)
Daytime (07:00 – 23:00)	V2	0.20
Night-Time (23:00 – 07:00)	V2	0.12



9.2 Re-radiated Noise Levels

Based on the maximum recorded vibration levels we have calculated predicted re-radiated noise levels within the proposed development at each floor. Predictions are made using the measurement data, the estimated train movement frequency detailed in Section 6.0 and medium amplification factors based on the proposed building structure. Noise levels will also decay slightly with height. A reasonable estimate is to subtract 1dB per floor.

The table below presents the predicted approximate re-radiated (L_{smax}) noise levels, based on our understanding of the proposed development.

Location	Level (dB L_{smax})
Level 0	29 – 35
Level 1	28 – 34
Level 2	27 – 33
Level 3	26 – 32

Please note that the upper range values are due to freight trains, and it is therefore not expected that this level would be experienced more than 16 times in a 24 hour period, assuming all scheduled freight trains run. The predicted reradiated noise from passenger trains is typically 2dB less than a typical freight train.

10.0 Discussion of Results

10.1 Vibration

The magnitude and frequency response of the measured vibration varied for each train pass-by. We believe this is mainly due to different types of trains (i.e passenger, freight etc) and the train movements being on different lines (different directions and distances from measurement positions). However, other factors to be considered which could cause a significant variance in vibration levels measured include the conditions of the ground, speed and weight of trains, as well as the condition of the rolling stock (i.e. rough wheels), and the condition of the tracks.

10.2 Tactile Vibration (BS 6472:2008)

With reference to the BS 6472:2008 criteria described within Section 5.2, predicted VDV levels fall within the “low probability of adverse comment” category.



10.3 Re-radiated Noise

The worst case predicted re-radiated daytime noise levels detailed in Section 0 are below the proposed criteria described in Section 5.2 for the proposed residential units, and therefore would usually be deemed acceptable.

Based on the aforementioned results, with respect to re-radiated noise, vibration isolation of the building may not need to be considered.

11.0 Conclusions

A new residential development is proposed on the existing site next to the rail tracks near Manchester Oxford Road station on Charles Street and York Street. A vibration survey has been undertaken to establish the current train induced vibration levels incident on 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.

With reference to the BS 6472:2008 criteria described within Section 5.1, predicted VDV levels fall within the “low probability of adverse comment” and should be acceptable.

The results of our assessment indicate that the predicted re-radiated noise levels are below the generally accepted criteria outlined in Section 5.2. As such, vibration in the form of re-radiated-radiated noise is likely acceptable and building isolation should not be required.

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.

Charles Street

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” (Third Edition), The Association of Noise Consultants. ISBN 978-0-9572543-2-9 (‘ANC Red Book’)

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. |

Vibration Dose Value (VDV) ($\text{m/s}^{1.75}$)

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 magnitude and frequency weighted r.m.s value of the acceleration and the quantity of train pass-bys.

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.