Technical Note

Title:	Camden Hostels - Construction Vibration Assessment, 248-250 Camden Road		
Client:	Morgan Sindall Construction & Infrastructure		
Reference:	2062267-RSKA-TN-001-(02)		
Date:	28 February 2024		
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1 Introduction

RSK Acoustics (RSKA) has been instructed by Morgan Sindall Construction & Infrastructure Limited to undertake a desktop vibration assessment of their proposed construction activities at 248 – 250 Camden Road, London (NW1 9HE). The site is located approximately 400 metres west of Caledonian Park and is accessed directly off Camden Road (A503). The proposed site plan is presented below:

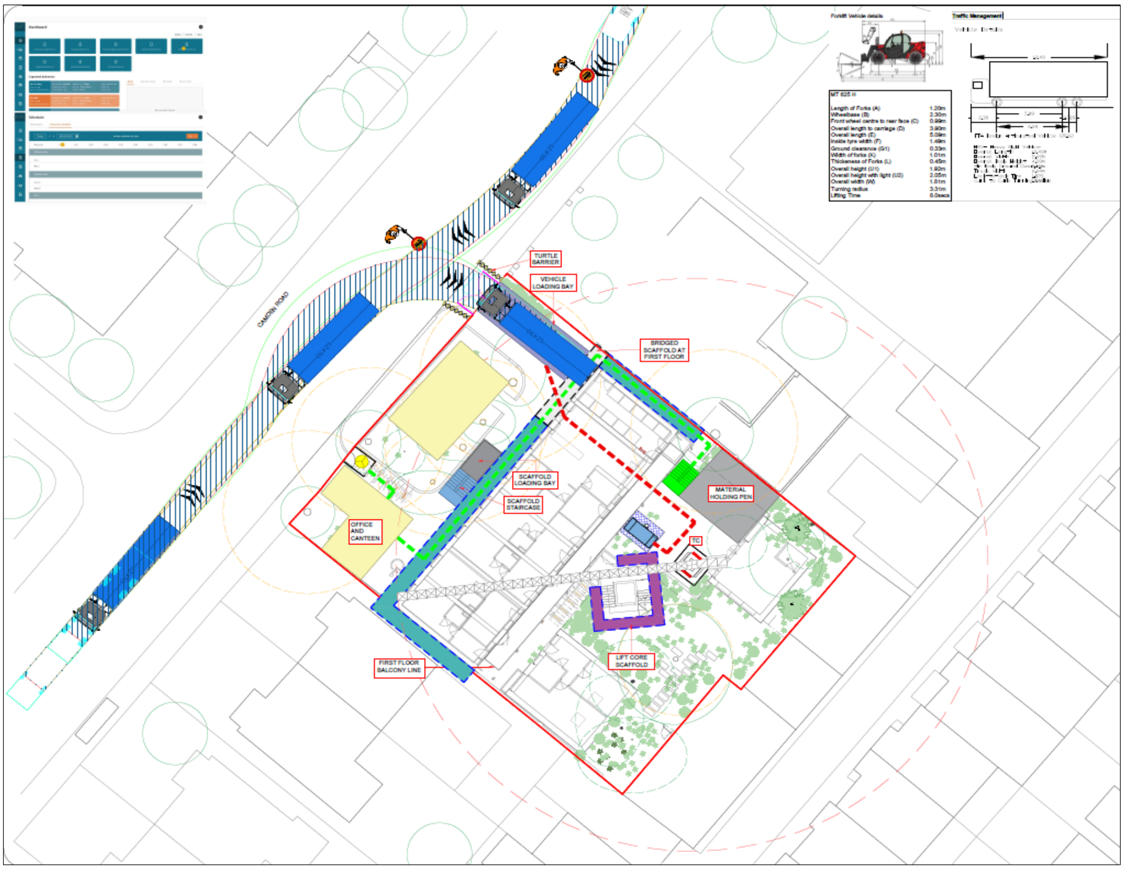

Figure 1.1 Proposed site plan (reproduced from drawing 'Logistic Proposal - P05 - S01 - R03', dated 13/12/23)

Site activity consists of the demolition of an existing four-storey short term housing centre and the erection of a new six-storey building to provide 39 new homes. To the rear of the site, it is understood that there are to be two additional buildings constructed, which include a single storey community room and wheelchair accessible home.

The main apartment block and buildings to the rear are understood to be built on piled foundations, with the main apartment block being pre-fabricated with a brick façade. The proposed main building will then be completed with a brick finish on ground floor and glazed terracotta tiles on the upper floors. Based on the supplied drawings, the south-west façade of the main building is understood to be approximately 1.5 metres from the nearest residential building at 246 Camden Road, with the façade of the opposite side of the main building (facing the north-east) approximately 2.2 metres from the nearest residential property at 252 Camden Road.

The proposed community room to the rear of the main block is understood to be approximately 2.5 metres from the garden boundary of 101 Camden Mews and approximately 2.7 metres from 99 Camden Mews. Distances from the wheelchair accessible annexe building to the neighbouring boundary wall have yet to be confirmed.

Discussions with the Client have been sought, which has isolated the following construction plant items likely to cause discernible levels of vibration; those include:

- 12 tonne excavator;
- 4 tonne roller;
- 5 tonne dumper;
- Sheet piling rig (vibratory or press-in piling);
- CFA rig capable of 450 mm diameter piles at circa 20 m deep; and
- Mobile concrete pump.

Given the early stages in the design of the groundwork/piling, there are no specific details regarding equipment specifications and likely locations of activities are indicative at present. The assessment has therefore adopted a conservative assessment methodology and assumed the equipment operates at closest distance of approach to the nearest sensitive receptors.

2 Methodology

British Standard 5228-2: 2009+A1: 2014 *'Code of practice for noise and vibration control on construction and open sites. Vibration'* (BS 5228-2), provides a series of calculation methodologies and historical data for various construction tasks including piling and compaction. In this instance, this assessment shall be informed by the information within this standard and RSKAs own, in-house monitoring data to inform likely vibration levels at nearest properties.

3 Assessment Criteria

3.1 Cosmetic Damage to Residential Property

British Standard 7385-2:1993 *'Evaluation and measurement for vibration in buildings. Guide to damage levels from groundborne vibration'* (reproduced in BS 5228-2) provides guide values to prevent cosmetic damage to property. Between 4 Hz and 15 Hz, a guide value of 15 - 20 mm/s peak particle velocity (PPV – greatest instantaneous particle velocity of the three perpendicular directions of measurement within a given time interval) is recommended for unreinforced and residential property, whist above 40 Hz the guide value is 50 mm/s PPV.

Table 3.1 and Figure 3.1 details the transient vibration guidance values to prevent the onset of cosmetic damage.

Line	Type of Building	Peak component particle velocity in frequency range of predominant pulse	
		4 Hz to 15 Hz	15 Hz and above
1	Reinforced or framed structures Industrial and heavy commercial buildings	50 mm/s at 4 Hz and above	
2	Unreinforced or light framed structures Residential or light commercial buildings	15 mm/s at 4 Hz increasing to 20 mm/s at 15 Hz	20 mm/s at 15 Hz increasing to 50 mm/s at 40 Hz and above

Note 1 – values referred to are at the base of the building;

Note 2 – for line 2, at frequencies below 4 Hz, a maximum displacement of 0.6 mm (zero to peak) is not to be exceeded.

Table 3.1 Transient vibration guide values for cosmetic damage (BS 7385-2, page 5)

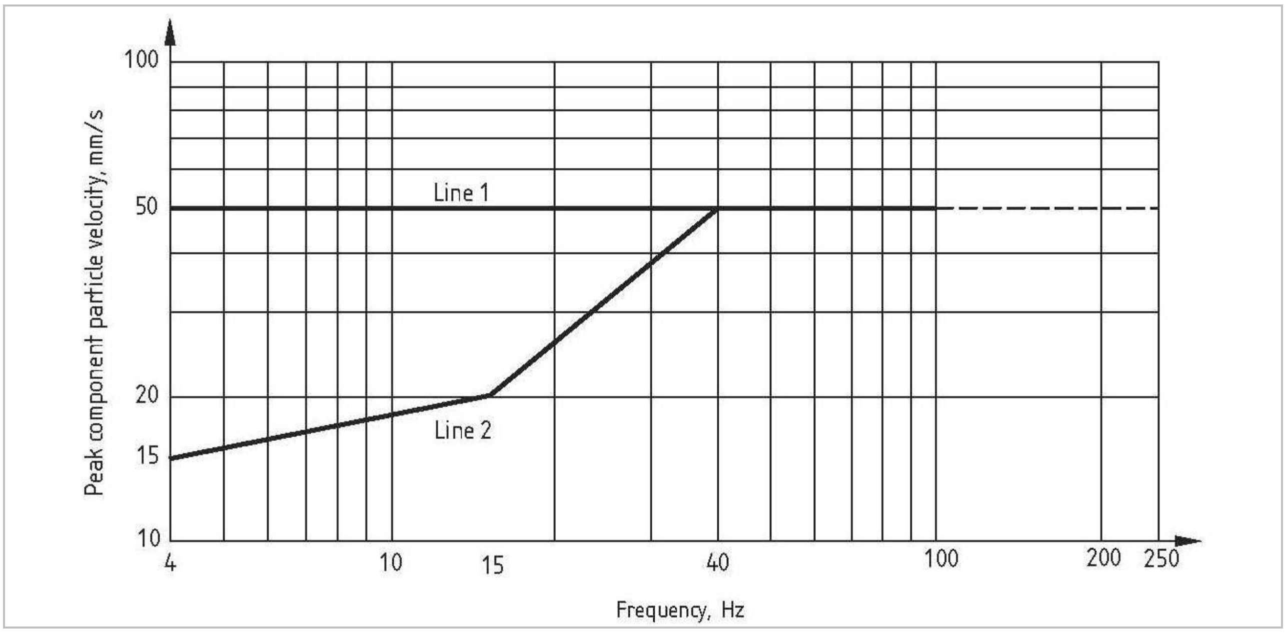

Figure 3.1 Transient vibration guide values for cosmetic damage (BS 7385-2, page 6)

According to BS 7385-2, *"Minor damage is possible at vibration magnitudes which are greater than twice those given for cosmetic damage, and major damage to a building structure may occur at values greater than four times the tabulated values"*.

Published damage criteria will not necessarily differentiate between these damage types, instead, the guidance values will be at such a level that precludes the onset of cosmetic damage and therefore automatically prevent any higher grade of damage.

3.2 Human Annoyance

In addition to criterion levels to prevent the onset of cosmetic damage, BS 5228-2 provides guidance on vibration levels to assess the likely impacts of construction activities on humans. Annex B of the standard gives guidance on the significance of vibration effects in terms of human response to vibration (Table 3.2 refers).

Vibration Level	Effect
0.14 mm/s	Vibration might be just perceptible in the most sensitive situations for most vibration frequencies associated with construction. At lower frequencies, people are less sensitive to vibration
0.3 mm/s	Vibration might be just perceptible in residential environments
1.0 mm/s	It is likely that vibration of this level in residential environments will cause complaint but can be tolerated if prior warning and explanation has been given to residents
10.0 mm/s	Vibration is likely to be intolerable for any more than a very brief exposure to this level

Table 3.2 Guidance on effects of vibration levels perceptible on humans

4 Likely Vibration Levels

4.1 CFA Piling

CFA piling is the preferred method of piling due to the significantly lower levels of vibration that would be generated when compared with other piling techniques i.e., vibratory or percussive. The use of CFA piling is also referenced in BS 5228-2 (Section 8.5.3) as a vibration mitigation measure i.e., an alternative method that is least likely to give rise to unacceptable levels of vibration. Section F3.2.4 of this standard provides the following statement in respect of vibration from CFA techniques:

"The levels of vibration associated with continuous flight auger injected piling and pressed-in piling are minimal, as the processes do not involve rapid acceleration or deceleration of tools in contact with the ground but rely to a large extent on steady motions. Continuous vibrations at a low level could be expected from the prime movers."

RSKA previously undertook monitoring of CFA piling in Maidstone (former South Essex College - August 2020) where a PPV level of 0.9 mm/s was measured at a distance of 18 metres. In addition, BS 5228-2 (Table D.6, Ref. no.105) provides measured data of rotary piling (using 600 mm diameter piles on soil formed of sands and gravels over chalk) at distances of 3.5 metres and 8 metres from the pile location. The resultant peak particle velocity vibration level was recorded at a level of 0.23 mm/s and 0.04 mm/s respectively.

Further historic data within BS 5228-2 (Table D.6, Ref. no. 106) indicates that PPV levels were measured between 0.22 and 0.54 at 5 metres from rotary piling activities using 600 mm diameter piles on soft ground over rock.

Based on a potential nearest distance from the installation of piles to the nearest residential property of approximately 4.8 metres, vibration produced by CFA piling, is unlikely to exceed the guidance criteria for the onset of cosmetic damage within Section 3 of this technical note (i.e., lower limit of 15 mms/s disregarding frequency). It is possible, however, that such levels may be perceivable (i.e., exceed 1.0 mm/s) and cause complaint if no prior warning is given to the nearest residents.

4.2 Excavators, Dumpers and Mobile Concrete Pump

It is understood that construction would also involve the use of a 12-tonne excavator, 5 tonne dumper and a mobile concrete pump, particularly during the enabling works, substructure and superstructure phases. BS 5228-2 does not provide historical data of vibration levels from the general movement of plant and equipment. In this case, given the less intrusive nature of these activities it is expected that levels of vibration from general operations of these plant items would not cause significant levels of vibration, nor exceed the guidance levels for cosmetic damage provided in Section 3 (i.e., lower limit of 15 mm/s disregarding frequency).

A recommended method for estimating PPV levels from construction equipment has been adopted from the guidance manual issued by the Federal Transit Administration '*Transit Noise and Vibration Impact Assessment Manual*', (2018) which is also referenced by Cadent Gas within its specification document for the protection of steel pipelines from vibratory-induced activities. PPV levels are obtained based on the reference vibration level from a list of construction equipment given in the guidance and the calculation of a propagation adjustment factor according to the following equation:

$$\boldsymbol{PPV = PPV_{ref} \times \left(\frac{10}{D}\right)^{1.5}}$$

Where:

- PPV = peak particle velocity in mm/s adjusted for distance
- PPV_{ref} = reference vibration level in mm/s at 10 metres
- D = distance from the equipment to the receiver in metres

Considering a reference vibration level of 1.5 mm/s at 10 metres for a large bulldozer (similar available plant from the reference list), predicted vibration levels from operational mobile plant similar in nature to the proposed excavators and dumpers would be expected to remain below the lower limit of 15 mm/s for distances of operation greater than 2.2 metres (likely operational scenario).

In addition, RSKA previously undertook monitoring of a Kobelco SK210 22 tonne excavator in Maidstone (former South Essex College - August 2020) where a PPV level of 3.4 mm/s at a distance of 5 metres was measured. It is understood that the proposed excavator during construction works at the Camden Road site is to be of a lower weight (12 tonne); therefore, the PPV levels considered for this plant item are deemed a conservative interpretation of the potential highest vibration levels generated by proposed plant. Furthermore, attended monitoring by RSKA of lorry and dumper movements measured maximum PPV levels of 0.4 mm/s at a distance of 4 metres. Typical discernible vibration levels from concrete pumps can be assumed to be of similar character and magnitude as idling lorries and mobile plant.

Based on the predicted and measured vibration levels of mobile plant, the predicted vibration levels at Camden Road are unlikely to exceed the guidance criteria for the onset of cosmetic damage; however, it is likely that such levels may cause complaint (i.e., exceed 1.0 mm/s).

4.3 Vibratory Rolling

Following discussions with the Client, potential vibration levels generated by vibratory compaction plant has also been considered in this desktop appraisal. The predicted vibration levels at a range of set back distances have been calculated below based on the empirical formulae given in *Annex E* of BS 5228-2.

Activity	Scaling Factor & Probability of Exceedance	PPV at a Range of Setback Distances (mm/s)			
		3 m	5 m	10 m	20 m
Vibratory Compaction (LTMG LTC40)	K_s = 276 (5%)	15.5	8.7	3.6	1.4
	K_s = 143 (33.3%)	8.0	4.5	1.9	0.7
	K_s = 75 (50%)	4.2	2.4	1.0	0.4
Calculation Parameters LTMG LTC40 twin drum roller (4T gross weight, with an amplification value of 0.5 mm and drum width of 1.3 m). Calculations based on a worst-case steady state regime rather than start-up and run-down condition. No allowance made for external to internal transfer function.					

Table 4.1 Vibration generated by Vibratory Compaction Plant – General Compaction

On the basis of the most onerous scaling factor 'K_s' of 276 which equates to a 5% probability of the predicted values being exceeded, the PPV values at a 5-metre setback distance are calculated to be 8.7 mm/s for vibration generated by vibratory compaction plant (*general compaction*).

With reference to BS 5228-2 assessment criteria, it is expected that levels of vibration from compaction activities would not exceed the guidance criteria for the onset of cosmetic damage. It is noted that resultant vibration levels have the potential to be feelable and cause complaint for the occupants of the adjacent properties at 252 and 246 Camden Road, if no prior warning is given to the residents.

4.4 Sheet Piling

Through correspondence with the Client, it is understood that, in addition to the CFA piling, there are to be sheet piles installed at a depth of approximately 3 metres around the perimeter of the development site to support excavation works.

Due to access constraints, the final piling methodology has not been adopted, with vibratory or press-in techniques being considered to complete the task.

Therefore, for the purposes of this appraisal, consideration has been given to the potential vibration levels generated from both vibratory and press-in piling methods.

Vibratory piling

The predicted vibration levels at a range of setback distances have been calculated below based on the empirical formulae given in *Annex E* of BS 5228-2.

Activity	Scaling Factor & Probability of Exceedance	PPV at a Range of Setback Distances (mm/s)			
		3 m	5 m	10 m	20 m
Vibratory Piling (sheet piling)	K_v = 266 (5%)	63.8	32.8	13.3	5.4
	K_v = 126 (33.3%)	30.2	15.5	6.3	2.6
	K_v = 60 (50%)	14.4	7.4	3.0	1.2
Calculation Parameters Calculations based assuming δ=1.3 (all operations). No allowance made for external to internal transfer function.					

Table 4.2 Vibration generated by Vibratory Piling – Sheet Piling Installation

On the basis of the most onerous scaling factor 'K_v' of 266 which equates to a 5% probability of the predicted values being exceeded, the PPV values at a 5-metre setback distance are calculated to be 32.8 mm/s for vibration generated by vibratory piling plant.

With reference to BS 5228-2 assessment criteria, resultant vibration levels have the potential to be intolerable for the occupants of those nearest properties situated at 252 and 246 Camden Road if works of this nature are undertaken for any more than a very brief period. Furthermore, with reference to BS 7385-2 guidance, if vibration levels were to persist at this level, there is potential for cosmetic damage to occur at these properties, depending on the frequency output of the activity.

In case sheet piling activities are planned at distances of 10 metres or more from nearest residential properties, worse case predicted PPV levels would be unlikely to exceed the vibration threshold for cosmetic damage.

Press-in piling

This technique has been developed to considerably reduce noise and vibration levels in order to operate in the most environmentally sensitive locations. The method hydraulically installs piles without vibration by static load making use of the 'reaction force' principle. In practical terms, the rig clamps previously installed piles and generates a reaction force from the negative skin friction and interlock resistance of these reaction piles. This reaction force provides press-in force to hydraulically jack subsequent piles into the ground. Since the piles are pressed-in, this technique minimises any damage to the environment.

In the absence of a recognised methodology to calculate the propagation of vibration levels using this technique, indicative predictions have been based on the empirical curves derived from field measurements of press-in piling activities published by Giken America Corporation in collaboration with Cambridge University Engineering Department and presented in the study *'Press-in piling: Ground vibration and noise during pile installation'*[1].

Activity	PPV at a Range of Setback Distances (mm/s)			
	3 m	5 m	10 m	20 m
Press-in Piling	2.3	1.4	0.7	0.35
Empirical formula: $V_{press\text{-}in}$ (mm/s) = 7 / r (m) with r=distance in metres from the rig (r≥1). It should be noted that the actual magnitude of vibrations will depend on soil properties and the local subsurface profile.				

Table 4.3 Vibration generated by Press-in Piling

Predicted levels derived from the empirical decay curve indicate that with the selection of the press-in piling technique PPV levels would likely sit comfortably below the vibration threshold for cosmetic damage at nearest receptors; however, the magnitude of the vibration may be perceptible by residents within a radius of approximately 50 metres from piling operations.

4.5 Concrete Breaking

It is understood that existing structures at basement level, including brick walls and slab floor, may warrant the need for concrete breaking activities. As such, likely vibration levels from concrete breaking have been included to inform any potential mitigation measures required prior to the commencement of the works.

In the absence of specific formulae in BS 5228-2 to calculate vibration levels from this task, data from a representative exercise measured by RSKA during concrete breaking activities of a car park area in Reigate, Surrey has been used. Vibration levels at various distances from a concrete slab were measured during the operation of a JCB 3CX ECO backhoe loader with a ProDem PRB100 breaker attachment (93 mm diameter and maximum impact energy of 1,350 Joule). Based on the individual vibration samples obtained during the monitoring exercise a trendline was created to provide a continuous prediction of the vibration decay under test conditions:

[1] Proceedings of the International Deep Foundations Congress. Orlando, USA

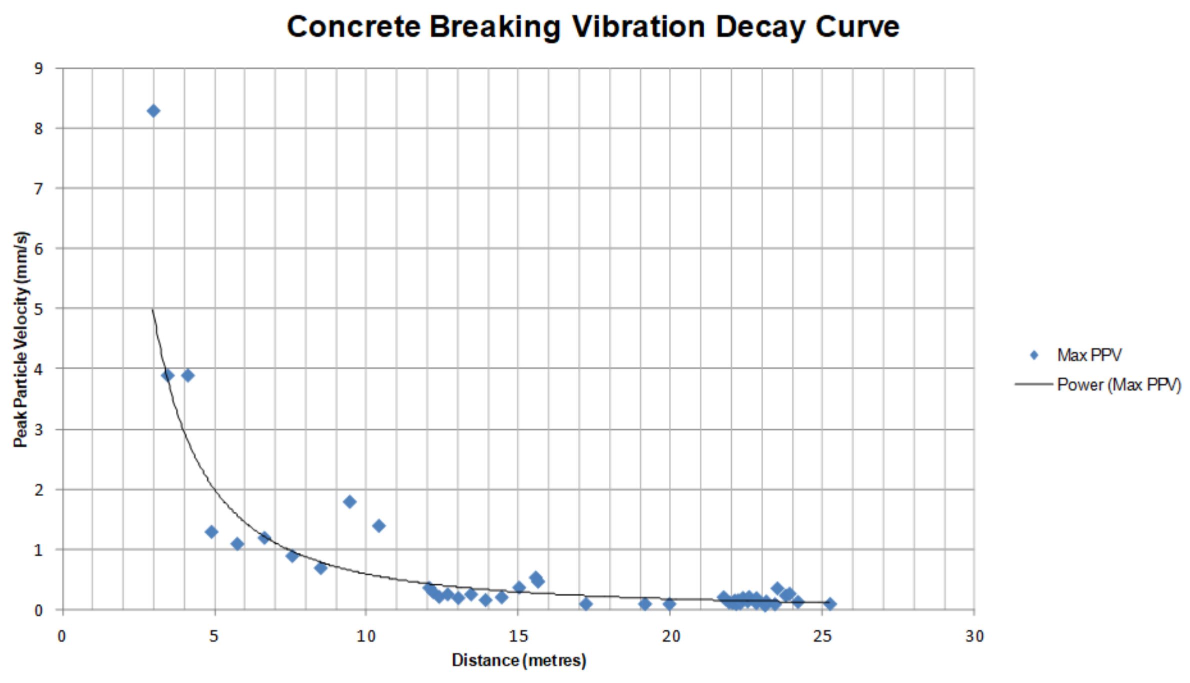

Figure 4.1 Ground vibration decay curve (concrete breaking)

A maximum vibration level of 8.3 mm/s was measured at a distance of 3 metres and decreased considerably to vibration levels below 3 mm/s, at a distance of 5 metres (and beyond) from the breaker.

In light of the above and considering that the nearest receptors to the concrete breaking activities at basement level would be situated in excess of approximately 12 metres distance from 246 and 252 Camden Road, vibration levels during concrete breaking activities are likely to remain within acceptable limits.

5 Discussion

Based on the assessment of likely vibration levels from proposed construction activity at the upcoming Camden Road construction site, vibration levels for most proposed activities are likely to remain below the lower limiting level of 15 mm/s for the onset of cosmetic damage to residential property. Vibration levels are predicted to exceed 1 mm/s in most cases which may cause complaint by adjacent receptors but can be tolerated if prior warning and explanation is given to residents.

Sheet piles are understood to be installed along the boundary of the site, in close proximity to 246 and 252 Camden Road. Depending on the final methodology adopted, predicted vibration levels have the potential to exceed the onset of cosmetic damage for residential properties and are likely to be intolerable for any more than a very brief exposure should vibratory piling be undertaken within a 10-metre radius, depending on the main frequency component. However, vibration levels with the adoption of press-in piling, deemed a significantly less intrusive technique, are unlikely to exceed the threshold for cosmetic criteria; vibration levels may still cause complaint by adjacent receptors but can be tolerated if prior warning and explanation is given to residents.

It should be noted that this assessment is based on historical data and empirical formula within BS 5228-2, third-party empirical studies and RSKA's inhouse data of similar operations.

Given the proximity of the proposed works to adjacent residential receptors, it is recommended that prior warning and explanation be given to residents and that monitoring be undertaken at strategic positions during the construction activity, the scale of which (number of positions and monitoring length) is not covered within this note. It is recommended that monitoring be undertaken adhering to the recommendations in Section 6 of this technical note and in line with the '*Guide for Contractors Working in Camden*' document (dated February 2008) issued by Camden London Borough Council, supplied by the Client.

6 Construction Monitoring

It is recommended that long-term vibration monitoring be conducted throughout the duration of the project where large scale plant items, such as the piling rig and movement of excavators/dumpers/rollers. The vibration monitor(s) should have the facility to measure (as a minimum) Peak Particle Velocity (PPV – in mm/s), at a suitable resolution to enable the vibration to be quantified against stipulated criteria. The instrumentation should be appropriate for the measurement of building vibration with respect to human response in line with ISO 8041- 1:2017 *'Human response to vibration — Measuring instrumentation — Part 1: General purpose vibration meters'*.

It is recommended that monitoring positions be chosen which provide a representative sample of the worst-case incidence on the receptors. The vibration monitor(s) should be buried, or suitably coupled to the ground in the horizontal position on a suitably flat, hard surface at the base of the receptor (or structure) via a ground spike and/or steel plate to the requirements of BS ISO 4866: 2010 '*Mechanical vibration and shock. Vibration of fixed structures. Guidelines for the measurement of vibrations and evaluation of their effects on structures*'.

The vibration monitor(s) should be installed with modem capability, enabling the real-time and historical noise data to be viewed via a dedicated web server. The system should allow for both 'amber and 'red' alert triggers to be set, in order to warn the construction team of criterion exceedances (via email or text). Trigger levels should be based on the guidance within Section 3 of this technical note.

If the 'amber' alert level is exceeded, a review of on-site activities should take place to check that working methodologies and the use of plant is in accordance with BPM and that appropriate onsite mitigation measures are in place. If the 'red' alert level is exceeded, the relevant works causing the high vibration levels should cease when safe to do so, and only recommended once ameliorative actions are undertaken.

Where the results of the vibration monitors corroborate that the measured levels are attributable to construction works, the following actions should be undertaken:

- Review the vibration monitoring data in conjunction with an acoustic specialist to determine as far as is reasonably practicable the activities / plant responsible for the exceedance(s); and
- Ascertain if there are any additional reasonably practicable means of reducing the construction vibration levels. Vibration criteria exceedances, causes, and any corrective action should be documented.

When necessary, and due to complaints or predicted levels of excessive vibration, additional attended vibration levels should be measured to validate both the predicted levels within this technical note and to ensure trigger levels are not exceeded at sensitive receptors. When attended measurements are being undertaken, the plant in operation should be checked to ensure appropriate Best Practicable Means (BPM) measures are being adopted and that working hours are adhered to.

7 Vibration Control Measures

Section 8 of BS 5228-2 gives recommendations for basic methods of vibration control relating to construction and open sites where work activities/operations generate significant vibration levels, including industry-specific guidance.

It has to be noted that vibration is generally more difficult to control than noise given the high dependency of the soil characteristics on its propagation and a more complex characterisation of vibratory sources; however, there are few generalizations which can be made about its control. It is also important to note that vibration can cause disturbance by causing structures to vibrate and radiate noise in addition to perceptible movement.

To avoid or reduce vibration levels from construction activity, several control measures and best practices can be implemented. These include:

- Pre-construction Surveys: Conduct pre-construction surveys to assess the baseline vibration levels in surrounding structures and sensitive areas.
- Planning and Scheduling: Plan construction activities to minimize vibration impact during sensitive times, such as avoiding night work or reducing activities during peak hours.
- Use of Low-Vibration Equipment: Employ modern construction equipment with low vibration characteristics, such as hydraulic breakers, saws, and compactors. Where reasonably practicable, plant and/or methods of work causing significant levels of vibration at sensitive premises should be replaced by other less intrusive plant and/or methods of working (e.g. the use of continuous flight auger injected piles, pressed-in preformed piles, auger bored piles, or possibly impact bored piles in preference to driven piles).
- Isolation Techniques: Install vibration isolation systems on heavy machinery and stationary equipment to minimise direct contact with the ground. Equipment should be relocated or isolated using resilient mountings when operating on connected structures or initially situated near sensitive premises.
- Vibration Monitoring: Continuously monitor vibration levels during construction activities using vibration sensors placed strategically around the site and where possible, at the base of most sensitive structures. This allows for immediate adjustments if levels exceed acceptable limits.
- Vibration Damping: Employ vibration damping materials or techniques on structures adjacent to construction sites to mitigate the transmission of vibrations.
- Regular Maintenance: Ensure regular maintenance and calibration of construction equipment to optimise performance and reduce vibration emissions.
- Community Engagement: Engage with local communities and stakeholders to communicate construction plans, potential impacts, and mitigation measures, fostering understanding and cooperation.

- Regulatory Compliance: Adhere to relevant regulations and standards concerning vibration emissions during construction activities.
- Training and Awareness: Train construction workers on vibration control measures and the importance of minimising vibration impacts on surrounding areas.

By implementing these measures, construction activities can effectively reduce or avoid adverse effects on surrounding structures, ecosystems, and communities due to vibration. Additionally, proactive planning and communication can help minimise disruptions and ensure smoother construction operations.

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