Partners in Planning and Architecture Ltd

Meldreth Station Yard Residential Development

Noise Assessment Report

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1. INTRODUCTION

As instructed by Partners in Planning and Architecture, and commissioned by London and County Homes, an assessment of noise and vibration impact has been carried out at the site of the proposed residential development on land adjacent to Meldreth Station. The eastern boundary of the site is alongside the railway running from London to Cambridge through Meldreth Station. The assessment has been carried out according to current planning policy requirements on noise and is based on the proposed layout plans.

This report updates the February 2017 report, following receipt of comments from the Environmental Health Officer and a revised site layout following a reduction in the number of residential units. An Acoustic Design Assessment and Statement have been undertaken according to the ProPG documnent 'Planning and Noise'.

The measurements and assessment have been carried out by John Hyde, a Chartered Physicist and Member of the Institute of Acoustics who has over 30 years' experience as a noise and acoustics consultant.

2. TERMINOLOGY

It has become practice to measure sound levels in decibels (dB). The decibel scale is logarithmic rather than linear. It is helpful to remember that a noise level change of 3dB on a sound meter reading would be just perceptible, and that an increase of 10 dB is perceived, subjectively, as a doubling of loudness. The human ear responds differently to sounds of different frequencies. The ear "hears" high frequency sound of a given level more loudly than low frequency sound of the same level. The A-weighted sound level, dB(A), takes this response into consideration and is commonly used for measurement of environmental noise in UK. It indicates the subjective human response to sound.

Environmental noise levels vary continuously from second to second. It is clearly impractical to specify the sound level for each second thus time averaging is required. In practice human response has been related to various units which include allowance for the fluctuating nature of sound with time. For the purpose of this report these include:

$L_{Aeq,T}$: the equivalent A-weighted continuous sound level over period T. This unit relates to the equivalent level of continuous sound for a specific time period T, for example 16 hr for daytime noise. It contains all the sound energy of the varying sound levels over the same time period, and expresses it as a continuous sound level over that period. The unit is used for assessing traffic, transportation and industrial noise for planning purposes.

$L_{A90,T}$: the A-weighted level of sound exceeded for 90% of the time period T. This latter unit is commonly used to represent the background noise, and is used in assessing the effects of industrial noise in UK.

L_{Amax} : the maximum A-weighted sound level over a period of measurement.

Vibration is a complex mechanism by which mechanical movement from a source is transmitted to a receiver. The source of vibration at this location is interaction between the wheels of trains which pass through the track and trackbed into the ground. Propagation through the ground is attenuated before reaching a building foundation but the degree of attenuation depends on soil and geological formations. Vibration enters buildings through the foundations where there is attenuation of the level but within a building there can be amplification of the vibration at upper floors.

The level of vibration generated by rail traffic depends on the surface irregularities of the wheels and rails and on the mass and speed of the trains, the higher the speed and mass, the higher the level of vibration likely to be generated. The level of vibration transmitted into the ground depends on the quality of the trackbed isolation through ballasting. Vibration attenuates rapidly with distance.

Vibration can be expressed in terms of displacement, velocity or acceleration, each of which vary with frequency and with time. Peak particle velocity (PPV) is often used to assess the impact of vibration in buildings as it correlates best with case history data and is usually measured in mm/s. The human body is sensitive to vibration and a perception threshold of approximately 0.3 mm/s is possible. Levels from 0.3 to 1.0mm/s can be perceptible but unlikely to cause disturbance. At levels of 1-2 mm/s vibration is clear and distinct while at levels above 3 mm/s people often express serious structural concerns even though, at this level, the risk of building damage resulting is extremely small.

3 NOISE AND VIBRATION CRITERIA

Planning Policy

The 'National Planning Policy Framework' (NPPF) (2012) gives three planning policy and decision aims in respect of noise:

- *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 the use of conditions, while recognising that many developments will create some noise; and*
- *Identify and protect areas of tranquility which have remained relatively undisturbed by noise and are prized for their recreational and amenity value for this reason*

As part of the framework, the 'Noise Policy Statement for England' (NPSE) (2010) reinforces the three policy aims on noise as follows:

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

It is possible to apply objective standards to the assessment of noise which uphold these policy aims. The effect of introducing a certain noise source may be determined by several methods, as follows:

- *The effect may be determined by reference to guideline noise values. BS8233:1999 'Sound insulation and noise reduction for buildings – A code of practice' and WHO 'Guidelines for Community Noise' contain such guidelines*
- *The effect may be determined by considering the change in noise level that would result from a proposal in an appropriate noise index for the characteristic of the noise in question.*
- *Another method is to compare the resultant noise level against the background noise level of the area, as used in BS4142:1997 to determine the likelihood of complaints from noise of an industrial nature*

Guidelines for Internal Noise

BS8233:1999 referred to in the policy has been superseded by BS8233:2014 and is relevant for this assessment. For residential property, the Standard suggests internal noise levels by day of 35dB(A) $L_{Aeq,16hr}$ (07:00-23:00) and 30dB(A) $L_{Aeq,8hr}$ in bedrooms during the night time (2300 - 0700).

These levels were originally recommended in 'Guidelines for Community Noise' by the World Health Organisation. These guidelines are frequently used by local authorities and are considered to be a good design standard for this type of assessment. The WHO Guidelines also recommend that maximum noise levels due to external events should not regularly exceed 45dB(A) in bedrooms at night.

External Noise Levels

The WHO Guidelines recommend that external noise levels in amenity areas, including gardens, should not exceed $L_{Aeq,16hr}$ 55dB.

Vibration Criteria

Guidance on effects of vibration is given in BS5228:2009 and BS6472:2008. BS5228 recommends the following criteria.

Vibration level	**Effect**
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 be clearly perceptible
10mm/s	Vibration is likely to be intolerable for any more than a very brief exposure to this level.

This means that vibration levels of less than 0.3mms^{-1} are unlikely to be perceptible and levels above 1mms^{-1} can cause disturbance to residents.

BS6472 recommends that the Vibration Dose Value inside residential buildings should achieve '*a low probability of adverse comment'* by not exceeding 0.2-0.4m.s$^{-1.75}$ during day time (0700-2300) and 0.1-0.2m.s$^{-1.75}$ at night (2300-0700).

ProPG Acoustic Design Statement

Following a request from South Cambs District Council an Acoustic Design Statement has been requested. This has been carried out according to the ProPG document 'Planning and Noise'. This has required the proposed layout to be assessed and noise measurements to be undertaken at the site, in order to assess the impact of ambient noise sources including local road traffic and the railway. This report details the results of all site measurements, considers the potential impact and recommends appropriate mitigation measures to meet planning guidance.

4 ACOUSTIC DESIGN ASSESSMENT

The design assessment is carried out in two stages. The first stage is a noise risk assessment of the potential noise impacts affecting the proposed site and the second stage is a systematic consideration of four key elements; acoustic design, internal noise levels, amenity area noise and other relevant issues

Stage 1 – Initial Site Noise Risk Assessment

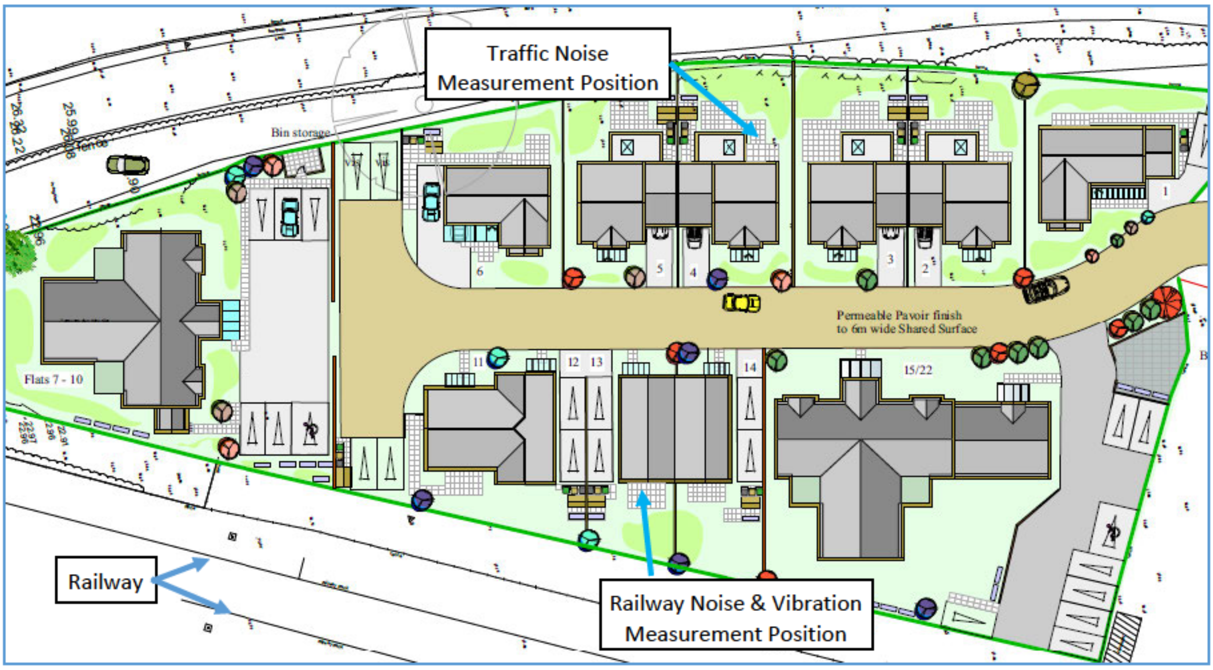
The site is located to the south of Meldreth Station and the railway line forms the eastern boundary, while Station Road forms the western boundary, as shown in Figure 1. Approximately 10 trains per hour pass though this route, clearly impacting on noise levels affecting the site, thus a noise survey was carried out to assess the likely impact. Due to the proximity of the railway, measurements of vibration were also undertaken at the same time as the noise survey.

Station Road links the villages of Melbourn and Meldreth and provides access to the A10. A separate survey of traffic noise was also carried out to assess the potential impact on the site.

Railway Noise

Measurements of railway noise were carried out on 31st January to 2nd February 2017 at the site of the proposed development. The noise measurement position was at the location of the rear façade of Plot 14, 13m from the railway as shown in Figure 1. Weather conditions throughout were dry and cold but with negligible wind. Conditions were foggy during the early morning of 1st February. None of the weather conditions were considered to have interfered with the measurements.

Figure 1: Site Plan and noise and vibration measurement positions



The noise measurements were carried out using a SVAN 977 Type I integrating sound level meter, serial no. 36438 which was calibrated before and after the measurement and no significant drifting of the calibration signal was observed. A copy of the instrument calibration certificate is available. The microphone was weather protected by an outdoor system and was mounted at 1.2m above ground in free field conditions.

Measurements were undertaken over a two day period and the following parameters were recorded:

- L_{Aeq} The equivalent continuous noise level over 15 minute periods
- L_{Amax} The maximum noise level during each hour
- L_{A90} The level exceeded for 90% of the time, the background level

In addition, octave band frequency levels were recorded for each period. The site was observed for about one hour during which time the main noise source was from the railway but traffic on Station Road could occasionally be heard although at a much lower level than the railway noise.

Staff involved with noise measurements were fully competent, either being Members of the Institute of Acoustics or holding a Certificate of Competence in Environmental Noise Measurement.

A summary of the results of the free field noise measurements is shown in Table 1 and the detailed results are shown in Appendix 1.

TABLE 1: Summary of results of railway noise measurements

Date	Average Daytime LAeq,T	Average Night time LAeq,T	Night time LAmax*
31-Jan	59.3	53.3	77.0
01-Feb	59.0	53.4	77.0

* Level exceeded 9 times on 31/1 and 6 times on 1/2

The day time façade $L_{Aeq,16hr}$ was therefore taken as 62dB, the night time $L_{Aeq,8hr}$ as 56dB and the night time L_{Amax} as 80dB, to the nearest 1 dB.

Railway Vibration

Vibration measurements were carried out at the same position as used for the noise measurements. The instrument used was a Vibrock 901 Seismometer and transducer, Serial No 1024, calibration reference 08161024. The transducer was mounted on the solid tarmac surface at the position equivalent to the distance of the closest residential façade to the railway. Measurements were undertaken over the same time period as the noise measurements. Vibration levels were measured as PPV in mm/s for 30 second periods throughout and the maximum level recorded for each 30 second period. As this generated over 5000 readings, the data was analysed in hourly periods and the maximum PPV was recorded for each hour.

The results of the measurements are summarised in Table 2 and shown in more detail in Appendix 2.

Table 2: Summary of vibration measurements

Average daytime PPV	0.60	mm/s
Average night time PPV	0.35	mm/s
Max. daytime PPV	0.80	mm/s
Max, night time PPV	0.78	mm/s

Vibration was not detected subjectively during the one hour observation period of the survey. The results indicated maximum vibration levels of 0.8mm/s.

Vibration dose values VDV were also measured with a second transducer. VDV measurements taken on open ground do not necessarily represent the likely values that will occur when the buildings are constructed as this depends on many factors, however, they give an indication of the potential vibration levels

The accelerometer was arranged so that the x-axis was parallel with the track in the horizontal plane, the y-axis was perpendicular to the track in the horizontal plane and the z-axis was in the vertical plane. The weighting Wb was applied to the vertical axis and Wd was applied to the two horizontal axis in line with BS6472-1:2008. During installation and collection of the equipment the weather conditions were suitable, as for the noise measurements, with dry ground surfaces.

Traffic Noise

Measurements of traffic noise were carried out on 13th June 2018 at 10m from the edge of Station Road at the position shown in Figure 1. The traffic noise was measured using the 'shortened method' recommended in the DoE document 'Calculation of Road Traffic Noise' (CRTN). This was considered appropriate as the traffic was freely flowing.

The method involved taking three consecutive hourly noise measurements between 10:00 and 16:00 from which the $L_{A10,18hr}$ and $L_{Aeq,16hr}$ could be predicted. Weather conditions throughout were dry and warm with a light south easterly wind. The free-field noise measurements were carried out at 1.2m above ground level, using a SVAN 955 sound level analyser, Serial No. 27330 and NOR-1251 Calibrator S/N 31057 for which calibration certificates are available. The meter was calibrated before and after the measurements and no significant drifting of the calibration signal was observed.

The following parameters were recorded:

- L_{Aeq} The equivalent continuous noise level over 15 minute periods
- L_{Amax} The maximum noise level during each period
- L_{A90} The level exceeded for 90% of the time, the background level
- L_{A10} The level exceeded for 10% of the time, used for the traffic noise measurement.

The results are shown in Table 1.

Table 1: Results of Noise Measurements

Date and Time		LAeq,15m [dB]	LAmax [dB]	LA10 [dB]	LA90 [dB]
13/06/2018	12:30	50.7	63.0	54.8	41.7
13/06/2018	12:45	51.3	64.4	54.7	40.2
13/06/2018	13:00	52.5	67.8	55.7	37.7
13/06/2018	13:15	50.1	60.6	53.2	40.8
13/06/2018	13:30	51.5	61.5	54.9	46.3
13/06/2018	13:45	52.0	63.2	54.6	48.6
13/06/2018	14:00	50.3	60.2	53.2	43.8
13/06/2018	14:15	49.9	60.5	53.3	40.6
13/06/2018	14:30	50.9	60.4	54.8	41.7
13/06/2018	14:45	54.1	68.2	58.5	41.0
13/06/2018	15:00	49.0	61.1	52.7	39.5
13/06/2018	15:15	51.0	72.1	54.0	41.5

The measured data was used to determine the $L_{Aeq,16hr}$ according to CRTN as follows:

LA10,1hr	12:30	54.6	dB
LA10,1hr	13:30	54.0	dB
LA10,1hr	14:30	55.0	dB
LA10,3hr Av.		54.5	dB
LA10,18hr		53.5	dB
LAeq,16hr		51.5	dB
LAeq,16hr (Façade)		54.5	dB
LAmax (Façade)		73.0	dB

Stage 2 – Assessment of Four Key Elements

Element 1 – Good Acoustic Design Process

As the major noise source affecting the site is from railway noise and the size of the site is restricted, the acoustic design options are severely limited. It is not practicable to use distance separation between the track and the dwellings and alternative layouts would not have any significant effect on noise impact at the building facades. The use of screening will be implemented to reduce noise in amenity areas by the installation of a noise barrier alongside the railway on the eastern boundary. Apart from this the only practicable acoustic design measure would be through building construction to ensure a high standard of internal noise levels, as considered in Element 2

Element 2 - Internal noise level guidelines

According to planning guidance and the requirements of BS8233:2014, the internal noise levels at the proposed development should not exceed $L_{Aeq.16hr}$ 35dB in living rooms, $L_{Aeq.8hr}$ 30dB in bedrooms at night and should not regularly exceed L_{Amax} 45dB in bedrooms at night. The closest approach of the eastern facades of the proposed dwellings to the railway, is at distance of 13m, the same distance from the track as the noise and vibration measurement position.

At this distance, the noise level at the would be $L_{Aeq,16hr}$ 62dB, $L_{Aeq,8hr}$ 56dB and the night time L_{Amax} 80dB, after allowing for the façade correction. This means that an overall sound reduction of 27dB would be required in order to meet the day time standard, 26dB to meet the night time standard and 35dB to meet the L_{Amax} requirement. Calculations of façade noise attenuation at the properties closest to the railway have been carried out according to BS8233:2014, where it was clear that the required internal noise levels could only be achieved with windows closed, thus ventilation measures would be needed. It was assumed that a typical through wall vent would be used providing a sound reduction R_w of 42dB.

The railway noise spectrum was taken from the octave band data at a time when the maximum noise level was 80dB. It was assumed that the tiled roof construction included minimum 100mm insulation above the ceilings which in turn consisted of a minimum 25mm plasterboard. Account was also taken of typical sound absorption in a living/bedroom. Façade and window dimensions were taken from the proposed plot and flat plans. The calculations are shown in Appendix 3.

The façade sound reduction using standard 4-16-4 double glazed units would be 30dB in typical living rooms facing the railway at Plots 11-14. This would meet the required target insulation of 27dB during the day time but not the 35dB attenuation for bedrooms at night. The calculation was repeated using typical bedroom dimensions from Plots 11-14 and acoustic double glazing comprising 6-16-6.8 laminated glass. The façade sound reduction was found to be 38dB which would then meet the required 35dB attenuation of maximum noise levels at night.

The sound attenuation ratings would only be achieved with windows closed, thus additional ventilation measures would be needed. For the bedrooms on the eastern facades, a through wall mechanical ventilator could be used to provide both background and purge ventilation, such as the AAF/S from Greenwood, an acoustic ventilator which gives a sound attenuation of $D_{n,ew}$ 43dB and supplies both background and purge ventilation on low and high settings. Products of similar specification from other manufacturers would be equally suitable.

Plots located on the western side of the site are likely to be affected by traffic noise on Station Road. The predicted daytime $L_{Aeq,16hr}$ of 55dB at the rear facades of plots 1-6 would require an attenuation of 20dB to meet the internal noise guideline of 35dB for living rooms. Standard 4-16-4 glazing would provide adequate sound attenuation and ventilation should be supplied through acoustic trickle vents in the window frames.

It is assumed that similar maximum noise level events due to passing vehicles would occur at night as during the day. The façade L_{Amax} 73dB at the rear facades of plots 1-6 would require an attenuation of 28dB to meet the WHO noise guideline of 45dB for maximum noise levels of events at night. This would be achieved using double glazing of 6-16-4 with acoustic trickle vents, as shown in the calculations in Appendix 5. This glazing would also ensure that the night time $L_{Aeq,8hr}$ internal noise guideline of 30dB would also be met.

The potential increase of traffic flow on Station Road due to that generated by the development, would result in an imperceptible noise increase of less than 1dB and the proposed mitigation would provide adequate attenuation for such an increase.

The façade insulation and ventilation requirements for all facades of the development is summarised in Table 3.

Table 3: Summary of Glazing and Ventilators

Plots	Façades	Bedrooms		Living Rooms	
		Glazing	Ventilators	Glazing	Ventilators
7-22	East North and South	6-16-6.8	M	4-16-4	M
1-6	West	6-16-4	TV	4-16-4	TV
7-22 west and 1-6 East	West	4-16-4	TV	4-16-4	TV

M Acoustic Mechanical Ventilator
TV Acoustic Trickle Vent

Element 3 - External amenity area noise

External noise levels in the gardens of Plots11-14 and in the amenity areas of the Flats facing the railway, would be $L_{Aeq,16hr}$ 59dB, as measured on the survey which exceeds the guideline level of 55dB. However, the proposed 2m close-board timber fence to be constructed along the boundary with the railway would provide effective screening of railway noise within the amenity and garden areas. This would reduce noise levels in these areas by 7-8dB and thus meet the guideline noise level.

Similar screening on the western boundary between Station Road and the rear gardens of Plots 1-6, would reduce the measured noise level of $L_{Aeq,16hr}$ 55dB to below 50dB and meet the required standard.

Element 4 – Assessment of other relevant issues

Due to the proximity of the railway to the proposed dwellings, an assessment of potential vibration disturbance was undertaken. The measurement survey showed that the highest PPV values of 0.8mm/s due to passing trains were above the BS5228 perception threshold of 0.3mm/s but below the 1.0mm/s criterion where complaints might be expected. However, it should be noted that these criteria apply to vibration levels measured inside a building, not on open ground. When entering the foundations of a building, the open ground measurement would be attenuated by the mass of concrete, typically by a factor of 0.5 and vibration levels at upper floors of the building can be amplified depending on the structure but such levels are unlikely to exceed the open ground values.

The results of the VDV measurements are shown in Appendix 4 and the day and night exposure levels calculated by the instrumentation according to BS6472-1:2008. The values are summarised in Table 4.

Table 4: Summary of VDV measurements

Date	VDV_{day}	VDV_{night}
	$m.s^{-1.75}$	$m.s^{-1.75}$
31-Jan	0.043	0.038
01-Feb	0.045	0.033

It is clear that the measured values were less than the BS6472 day time criterion of 0.2-0.4$m.s^{-1.75}$ and less than the night time criterion of 0.1-0.2$m.s^{-1.75}$. As for the PPV assessment, vibration levels within the proposed dwellings are difficult to predict prior to construction but should not exceed the open ground measurements.

Occupiers of the proposed dwellings would have clearly chosen to live next to the railway and would associate any detectable vibration with noise from passing trains. Consequently, their acceptance of such vibration is likely to be greater than that of the average population living away from railways.

5 ACOUSTIC DESIGN STATEMENT

The acoustic design statement takes account of the findings of the Acoustic Design Assessment. The following issues have been considered:

- Relevant noise sources have been identified as arising from the railway on the eastern boundary and, to a lesser extent, from traffic on Station Road on the western boundary.
- Based on measured noise data the site was assessed as between low and medium risk according to ProPG cirteria
- Due to the nature of the noise source and restricted site size, mitigation measures were limited. Source separation, use of buildings as screens, use of quiet facades for noise sensitive rooms and site layout options were not practicable measures to reduce noise impact.
- Boundary screening is proposed to reduce external noise levels in amenity areas and to ground floor building facades.
- Window sizes have been minimised for bedrooms on the proposed dwellings in order to maximise the composite sound attenuation of the facades.
- Calculations of façade sound attenuation have been carried out according to BS8233:2014 Annexe G2 and appropriate glazing measures recommended to meet the ProPG Internal Noise Guidelines.
- As windows would need to remain closed, acoustic ventilation measures have been recommended and taken into account in the façade attenuation calculations.

6 CONCLUSIONS

Railway noise and vibration levels have been measured at the proposed development at Meldreth Station and have been assessed according to ProPG, national planning guidance, the internal noise standards of BS8233:2014 and the vibration criteria of BS5228:2009 and BS6472:2008. These standards for day and night time levels would be achieved through the following measures:

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- Windows to all living rooms meet a minimum glazing requirement of 4mm-16mm-4mm float glass.
- Windows to bedrooms on the eastern, northern and southern facades of Plots 7-10, 11-14 and 15-22 meet a minimum glazing requirement of 6mm-16mm-6.8mm laminated glass.
- The ceilings of these bedrooms at roof level should be constructed from a minimum of 25mm plasterboard with minimum 100mm mineral wool insulation above the ceiling.
- Ventilation to these bedrooms is provided by means of a mechanical through-wall acoustic ventilator which provides both background and purge ventilation such as the AAF/S or a similar product from an alternative manufacturer.
- Windows to bedrooms on the western facades of Plots 1-6 should meet a minimum glazing requirement of 6mm-16mm-4mm float glass
- The remaining bedroom windows throughout the site to be fitted with 4mm-16mm-4mm glazing with background ventilation through acoustic trickle vents and purge ventilation through open windows.
- A 2m close boarded fence should be constructed along the eastern boundary alongside the railway and on the western boundary alongside Station Road, to reduce external noise levels in amenity areas so as to meet the relevant guidelines.
- Railway vibration levels have been assessed and based on measurements, were found to be within the recommended criteria of BS6472:2008 and unlikely to cause significant disturbance to occupiers.

APPENDIX 1

Start date & time	LAmax	LAeq	LA90
	[dB]	[dB]	[dB]
31/01/2017 16:00	71.7	56.1	52.7
31/01/2017 16:15	84.0	60.7	51.0
31/01/2017 16:30	82.3	59.4	54.1
31/01/2017 16:45	81.7	59.8	51.8
31/01/2017 17:00	80.7	58.5	52.4
31/01/2017 17:15	83.3	61.3	51.5
31/01/2017 17:30	79.8	58.2	52.1
31/01/2017 17:45	86.6	65.5	53.5
31/01/2017 18:00	74.3	57.5	53.3
31/01/2017 18:15	89.4	63.5	52.5
31/01/2017 18:30	67.4	55.6	51.7
31/01/2017 18:45	79.9	58.3	52.5
31/01/2017 19:00	80.0	58.4	50.6
31/01/2017 19:15	84.0	61.7	50.8
31/01/2017 19:30	67.6	54.3	51.1
31/01/2017 19:45	79.7	56.2	50.4
31/01/2017 20:00	70.8	53.6	48.2
31/01/2017 20:15	76.7	55.3	46.8
31/01/2017 20:30	80.4	58.9	48.7
31/01/2017 20:45	80.4	56.8	46.7
31/01/2017 21:00	67.9	51.9	47.3
31/01/2017 21:15	86.9	61.2	46.5
31/01/2017 21:30	76.0	55.9	47.4
31/01/2017 21:45	80.7	58.5	47.7
31/01/2017 22:00	73.1	52.7	45.5
31/01/2017 22:15	82.2	58.4	42.4
31/01/2017 22:30	89.5	62.7	46.1
31/01/2017 22:45	79.8	54.3	44.3
31/01/2017 23:00	79.7	62.8	42.2
31/01/2017 23:15	77.8	53.3	36.8
31/01/2017 23:30	67.2	48.6	40.5
31/01/2017 23:45	80.0	54.3	40.7
01/02/2017 00:00	56.0	44.8	38.7
01/02/2017 00:15	80.1	54.2	37.1
01/02/2017 00:30	58.7	42.4	35.5
01/02/2017 00:45	56.6	42.5	34.6
01/02/2017 01:00	64.8	45.3	33.2
01/02/2017 01:15	54.5	41.8	33.2
01/02/2017 01:30	58.7	43.9	33.6
01/02/2017 01:45	58.1	42.9	33.7
01/02/2017 02:00	55.4	42.5	34.6
01/02/2017 02:15	59.0	44.6	34.0
01/02/2017 02:30	55.8	42.6	33.2
01/02/2017 02:45	55.4	39.5	32.1
01/02/2017 03:00	57.0	42.5	32.3
01/02/2017 03:15	58.7	44.0	34.0
01/02/2017 03:30	58.2	43.8	32.5
01/02/2017 03:45	57.4	42.9	32.5

Start date & time	LAmax	LAeq	LA90
	[dB]	[dB]	[dB]
01/02/2017 04:00	58.0	42.4	33.1
01/02/2017 04:15	54.2	40.7	32.3
01/02/2017 04:30	58.4	45.4	32.5
01/02/2017 04:45	57.1	47.0	35.3
01/02/2017 05:00	55.5	46.0	38.6
01/02/2017 05:15	80.2	54.5	40.3
01/02/2017 05:30	56.9	49.8	42.2
01/02/2017 05:45	81.0	60.0	44.9
01/02/2017 06:00	58.9	51.6	46.3
01/02/2017 06:15	80.2	57.4	45.5
01/02/2017 06:30	79.2	59.3	49.9
01/02/2017 06:45	80.0	58.5	51.6
01/02/2017 07:00	77.6	58.0	52.1
01/02/2017 07:15	80.7	59.8	51.7
01/02/2017 07:30	68.3	56.3	53.0
01/02/2017 07:45	79.3	59.2	53.5
01/02/2017 08:00	72.1	56.6	53.9
01/02/2017 08:15	80.9	59.8	54.0
01/02/2017 08:30	73.7	57.3	54.1
01/02/2017 08:45	79.5	58.9	53.6
01/02/2017 09:00	80.3	58.3	53.0
01/02/2017 09:15	81.4	58.7	50.7
01/02/2017 09:30	79.7	59.4	50.7
01/02/2017 09:45	78.7	57.0	50.3
01/02/2017 10:00	80.2	57.0	48.2
01/02/2017 10:15	81.4	59.5	48.8
01/02/2017 10:30	83.8	62.2	51.3
01/02/2017 10:45	82.0	59.7	51.4
01/02/2017 11:00	74.7	54.8	50.1
01/02/2017 11:15	80.7	58.3	50.1
01/02/2017 11:30	88.0	66.2	49.3
01/02/2017 11:45	82.6	59.7	48.5
01/02/2017 12:00	73.1	53.9	48.1
01/02/2017 12:15	80.5	58.1	46.5
01/02/2017 12:30	79.3	57.1	45.6
01/02/2017 12:45	82.7	62.6	46.7
01/02/2017 13:00	73.7	54.6	47.1
01/02/2017 13:15	81.7	58.4	47.6
01/02/2017 13:30	80.2	57.1	48.0
01/02/2017 13:45	79.6	57.2	45.9
01/02/2017 14:00	79.7	55.4	45.5
01/02/2017 14:15	83.7	59.9	45.2
01/02/2017 14:30	80.0	56.7	45.5
01/02/2017 14:45	81.1	57.3	47.8
01/02/2017 15:00	79.9	58.0	47.5
01/02/2017 15:15	83.0	59.7	47.3
01/02/2017 15:30	80.2	58.4	48.6
01/02/2017 15:45	81.0	59.5	49.1

Start date & time	LAmax [dB]	LAeq [dB]	LA90 [dB]
01/02/2017 16:00	74.8	55.3	50.9
01/02/2017 16:15	81.2	59.9	50.0
01/02/2017 16:30	68.4	54.3	51.1
01/02/2017 16:45	84.8	62.2	50.5
01/02/2017 17:00	79.8	57.1	51.9
01/02/2017 17:15	83.1	61.8	51.2
01/02/2017 17:30	68.5	53.1	50.2
01/02/2017 17:45	83.5	65.1	50.4
01/02/2017 18:00	67.3	53.8	50.7
01/02/2017 18:15	84.5	60.5	48.0
01/02/2017 18:30	67.5	53.5	49.5
01/02/2017 18:45	84.3	60.3	49.3
01/02/2017 19:00	70.8	54.6	51.0
01/02/2017 19:15	81.8	60.8	49.8
01/02/2017 19:30	67.9	53.2	48.6
01/02/2017 19:45	81.4	58.4	46.8
01/02/2017 20:00	74.1	53.1	45.9
01/02/2017 20:15	79.6	57.9	46.3
01/02/2017 20:30	80.7	55.7	44.4
01/02/2017 20:45	83.4	59.9	44.2
01/02/2017 21:00	69.0	51.2	43.3
01/02/2017 21:15	81.3	60.1	44.0
01/02/2017 21:30	80.9	57.3	45.9
01/02/2017 21:45	72.5	60.3	41.7
01/02/2017 22:00	68.6	50.5	42.4
01/02/2017 22:15	80.7	57.9	43.6
01/02/2017 22:30	83.1	61.8	38.3
01/02/2017 22:45	81.0	56.0	37.0
01/02/2017 23:00	68.3	47.8	37.6
01/02/2017 23:15	85.1	62.9	33.3
01/02/2017 23:30	72.3	50.3	36.2
01/02/2017 23:45	80.2	53.5	34.2
02/02/2017 00:00	75.4	49.1	32.2
02/02/2017 00:15	79.5	52.5	30.8
02/02/2017 00:30	56.9	43.5	32.2
02/02/2017 00:45	54.9	40.2	31.4
02/02/2017 01:00	63.4	44.9	32.9
02/02/2017 01:15	56.4	40.0	31.8
02/02/2017 01:30	58.9	40.8	30.0
02/02/2017 01:45	56.2	41.2	30.4
02/02/2017 02:00	52.0	37.5	28.8
02/02/2017 02:15	52.2	39.1	30.9
02/02/2017 02:30	54.4	38.4	31.0
02/02/2017 02:45	58.8	41.8	32.2
02/02/2017 03:00	58.1	41.9	31.5
02/02/2017 03:15	59.8	41.7	31.6
02/02/2017 03:30	59.5	42.5	33.7
02/02/2017 03:45	58.5	44.2	33.5
02/02/2017 04:00	60.2	42.8	33.2
02/02/2017 04:15	55.1	41.2	32.5
02/02/2017 04:30	54.9	43.9	34.0
02/02/2017 04:45	58.6	46.6	35.2
02/02/2017 05:00	59.7	47.3	39.0
02/02/2017 05:15	78.7	53.5	39.9
02/02/2017 05:30	83.7	61.4	41.0
02/02/2017 05:45	78.6	54.6	41.7
02/02/2017 06:00	63.7	52.4	46.6
02/02/2017 06:15	63.0	53.6	50.4
02/02/2017 06:30	72.3	54.8	50.2
02/02/2017 06:45	82.4	61.4	52.0
02/02/2017 07:00	79.6	58.8	53.2
02/02/2017 07:15	84.3	61.4	53.2
02/02/2017 07:30	68.2	57.5	54.3
02/02/2017 07:45	82.8	61.1	53.9
02/02/2017 08:00	72.5	57.3	55.1
02/02/2017 08:15	81.7	60.8	54.1
02/02/2017 08:30	93.8	67.8	58.2
02/02/2017 08:45	68.2	68.1	68.0
02/02/2017 09:00	68.3	68.2	68.0

APPENDIX 2

Results of Hourly Maximum Vibration PPV Levels

Date	Hour Commencing	Time of max PPV	Max PPV mm/s
31-Jan	1400	1450	0.52
	1500	1520	0.52
	1600	1643	0.61
	1700	1723	0.59
	1800	1822	0.49
	1900	1926	0.55
	2000	2053	0.66
	2100	2153	0.64
	2200	2224	0.67
	2300	2301	0.78
01-Feb	0000	0027	0.46
	0100	0109	0.15
	0200	0200	0.15
	0300	0300	0.15
	0400	0400	0.15
	0500	0546	0.75
	0600	0625	0.57
	0700	0751	0.42
	0800	0851	0.40
	0900	0919	0.56
	1000	1049	0.66
	1100	1130	0.79
	1200	1220	0.58
	1300	1351	0.66
	1400	1424	0.80
	1500	1520	0.57
	1600	1645	0.65
	1700	1724	0.55
	1800	1823	0.55
	1900	1955	0.57
	2000	2055	0.60
	2100	2153	0.76
	2200	2241	0.61
	2300	2315	0.48
02-Feb	0000	0023	0.43
	0100	0105	0.15

Date	Hour	Time	Max PPV
	Commencing	of max PPV	mm/s
	0200	0200	0.15
	0300	0300	0.15
	0400	0400	0.15
	0500	0543	0.65
	0600	0656	0.23
	0700	0721	0.42
	0800	0818	0.67
	0900	0920	0.61
Average daytime PPV		0.60	mm/s
Average night time PPV		0.35	mm/s
Max. daytime PPV		0.80	mm/s
Max, night time PPV		0.78	mm/s

APPENDIX 3

Façade Sound Insulation Calculations of Railway Noise

Façade Sound Reduction of Bedroom at Plot 13 on Eastern Façade facing railway						
Facade Area	12.5					
Window Area	2.1					
Ceiling/Roof Area	15					
Frequency	**125**	**250**	**500**	**1000**	**2000**	**LAeq**
Façade Leq	55.1	53.9	51.8	54.1	52.4	57.7
Ventilator Dne	33	38	40	48	50	
Window R (6-16-6.8)	22	27	35	42	41	
Wall R	37	42	52	60	63	
Ceiling R	27	37	43	48	52	
Absorption	11	14	16	16	15	
Vent	0.000182	5.76E-05	3.64E-05	5.76E-06	3.64E-06	
	-37.3933	-42.3933	-44.3933	-52.3933	-54.3933	
Window	0.000482	0.000152	2.41E-05	4.82E-06	6.07E-06	
	-33.1711	-38.1711	-46.1711	-53.1711	-52.1711	
Ext. Wall	7.55E-05	2.39E-05	2.39E-06	3.78E-07	1.9E-07	
	-41.223	-46.223	-56.223	-64.223	-67.223	
Ceiling	0.001088	0.000109	2.73E-05	8.64E-06	3.44E-06	
	-29.6324	-39.6324	-45.6324	-50.6324	-54.6324	
Composite R	-27.3806	-34.651	-40.4462	-47.0764	-48.7506	
Abs. Correction	3.9794	2.932047	2.352127	2.352127	2.632414	
Leq (int)	31.7	22.2	13.7	9.4	6.3	
A-Weighting	-16.1	-8.6	-3.2	0	1.2	
LAeq (internal)	15.6	13.6	10.5	9.4	7.5	19.3
Façade Atten.	**38.4**	**dB**				

Façade Sound Reduction Living Room at Ground Floor of Plot 13 facing the railway						
Facade Area	13.0					
Window Area	6.8					
Ceiling/Roof Area	0.0					
Frequency	**125**	**250**	**500**	**1000**	**2000**	**LAeq**
Façade Leq	55.1	53.9	51.8	54.1	52.4	57.7
Ventilator Dne	33	38	40	48	50	
Window R (4-16-4)	21	17	25	35	37	
Wall R	37	42	52	60	63	
Ceiling R	27	37	43	48	52	
Absorption	11	14	16	16	15	
Vent	0.000385	0.000122	7.69E-05	1.22E-05	7.69E-06	
	-34.1398	-39.1398	-41.1398	-49.1398	-51.1398	
Window	0.004155	0.010436	0.001654	0.000165	0.000104	
	-23.8147	-19.8147	-27.8147	-37.8147	-39.8147	
Ext. Wall	9.52E-05	3.01E-05	3.01E-06	4.77E-07	2.39E-07	
	-40.2159	-45.2159	-55.2159	-63.2159	-66.2159	
Ceiling	1.53E-07	1.53E-08	3.85E-09	1.22E-09	4.85E-10	
	-68.1398	-78.1398	-84.1398	-89.1398	-93.1398	
Composite R	-23.3391	-19.7519	-27.6097	-37.4942	-39.4966	
Abs. Correction	0.725841	-0.32151	-0.90143	-0.90143	-0.62115	
Leq (int)	32.5	33.8	23.3	15.7	12.3	
A-Weighting	-16.1	-8.6	-3.2	0	1.2	
LAeq (internal)	16.4	25.2	20.1	15.7	13.5	27.3
Façade Atten.	**30.4**	**dB**				

APPENDIX 4

Results of Vibration Dose Value Measurements

Date	Hour	X	Y	Z	VDV
	Commencing	$m.s^{-1.75}$	$m.s^{-1.75}$	$m.s^{-1.75}$	$m.s^{-1.75}$
31-Jan	1400	0.005	0.009	0.012	0.013
	1500	0.005	0.006	0.024	0.024
	1600	0.006	0.006	0.022	0.022
	1700	0.009	0.006	0.020	0.020
	1800	0.009	0.009	0.019	0.019
	1900	0.008	0.007	0.019	0.019
	2000	0.009	0.007	0.012	0.013
	2100	0.006	0.006	0.016	0.016
	2200	0.005	0.009	0.027	0.027
	2300	0.009	0.006	0.025	0.025
01-Feb	0000	0.006	0.005	0.016	0.016
	0100	0.005	0.008	0.029	0.029
	0200	0.009	0.005	0.005	0.009
	0300	0.005	0.008	0.007	0.009
	0400	0.009	0.008	0.009	0.011
	0500	0.005	0.008	0.015	0.015
	0600	0.009	0.006	0.029	0.029
	0700	0.005	0.005	0.018	0.018
	0800	0.005	0.009	0.023	0.023
	0900	0.007	0.009	0.022	0.022
	1000	0.006	0.009	0.024	0.024
	1100	0.006	0.009	0.019	0.019
	1200	0.009	0.006	0.013	0.014
	1300	0.007	0.008	0.024	0.024
	1400	0.008	0.006	0.024	0.024
	1500	0.008	0.005	0.023	0.023
	1600	0.005	0.009	0.025	0.025
	1700	0.008	0.009	0.021	0.021
	1800	0.008	0.009	0.019	0.019
	1900	0.007	0.008	0.016	0.016
	2000	0.009	0.005	0.023	0.023
	2100	0.009	0.006	0.030	0.030
	2200	0.006	0.006	0.012	0.012
	2300	0.008	0.009	0.015	0.016
02-Feb	0000	0.009	0.008	0.018	0.018
	0100	0.005	0.009	0.019	0.019
	0200	0.009	0.006	0.006	0.010
	0300	0.008	0.007	0.005	0.009

Date	Hour	X	Y	Z	VDV
	Commencing	$m.s^{-1.75}$	$m.s^{-1.75}$	$m.s^{-1.75}$	$m.s^{-1.75}$
	0400	0.008	0.006	0.006	0.009
	0500	0.005	0.009	0.029	0.029
	0600	0.005	0.005	0.014	0.014
	0700	0.006	0.007	0.020	0.020
	0800	0.007	0.008	0.024	0.024
	0900	0.008	0.005	0.012	0.013

APPENDIX 5

Façade sound attenuation of traffic noise on Station Road

Façade Sound Reduction - Plot 1 Living Room						
Facade Area	7.2					
Window Area	4.4					
Ceiling/roof Area	0					
Room Vol.	39.6					
Frequency (Hz)	125	250	500	1000	2000	LAeq
Measured Façade Leq	60.3	52.9	49.0	50.2	48.1	**54.5**
Ventilator Dne	25	25	26	32	35	
Window R	21	17	25	35	37	
Wall R	40	44	45	51	56	
Ceiling/Roof R	28	34	40	45	49	
Absorption	11	14	16	16	15	
Vent	0.004386	0.004386	0.003484	0.000875	0.000439	
Trickle	-23.6	-23.6	-24.6	-30.6	-33.6	
Windows	0.004847	0.012176	0.001930	0.000193	0.000122	
(4/16/4)	-23.1	-19.1	-27.1	-37.1	-39.1	
Ext. Wall	0.000039	0.000015	0.000012	0.000003	0.000001	
(Cavity Wall)	-44.1	-48.1	-49.1	-55.1	-60.1	
Ceiling/roof	0.000002	0.000001	0.000000	0.000000	0.000000	
	-56.6	-62.6	-68.6	-73.6	-77.6	
Composite R	-20.3	-17.8	-22.7	-29.7	-32.5	
Abs. Correction	-1.8	-2.9	-3.5	-3.5	-3.2	
Leq (int)	38.2	32.2	22.9	17.1	12.5	
A-Weighting	-16.1	-8.6	-3.2	0	1.2	
LAeq (internal)	22.1	23.6	19.7	17.1	13.7	**27.4**
Façade Atten.	**27.0**	**dB**				

Façade Sound Reduction - Plot 1 Bedroom						
Facade Area	9.6					
Window Area	3.2					
Ceiling/roof Area	16					
Room Vol.	38.4					
Frequency (Hz)	125	250	500	1000	2000	LAeq
Measured Façade Leq	60.3	52.9	49.0	50.2	48.1	**54.5**
Ventilator Dne	35	35	36	42	45	
Window R	21	20	26	38	37	
Wall R	40	44	45	51	56	
Ceiling/Roof R	28	34	40	45	49	
Absorption	11	14	16	16	15	
Vent	0.000124	0.000124	0.000098	0.000025	0.000012	
5000EA	-39.1	-39.1	-40.1	-46.1	-49.1	
Windows	0.000993	0.001250	0.000314	0.000020	0.000025	
(6/16/4)	-30.0	-29.0	-35.0	-47.0	-46.0	
Ext. Wall	0.000025	0.000010	0.000008	0.000002	0.000001	
(Cavity Wall)	-46.0	-50.0	-51.0	-57.0	-62.0	
Ceiling/roof	0.000991	0.000249	0.000063	0.000020	0.000008	
	-30.0	-36.0	-42.0	-47.0	-51.0	
Composite R	-26.7	-27.9	-33.2	-41.8	-43.4	
Abs. Correction	3.7	2.6	2.0	2.0	2.3	
Leq (int)	37.3	27.6	17.9	10.5	7.1	
A-Weighting	-16.1	-8.6	-3.2	0	1.2	
LAeq (internal)	21.2	19.0	14.7	10.5	8.3	**24.1**
Façade Atten.	**30.3**	**dB**				