SANDY BROWN

Consultants in Acoustics, Noise & Vibration

RM1/OBJ/9

PROOF OF EVIDENCE of RICHARD MUIR (MSc BSc CEng MIOA MIMechE)
of SANDY BROWN LIMITED on behalf of the Medical Research Council

Noise and Vibration

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1 QUALIFICATIONS AND EXPERIENCE

1.1 My full name is Richard Muir. I hold a Master of Science Degree in Environmental Acoustics and a Bachelor of Science Degree in Mechanical Engineering. I am a Chartered Engineer, a Member of the Institute of Acoustics, and a Member of the Institution of Mechanical Engineers. Most of my 36-year working career has been focused on environmental noise and vibration control and the acoustic design of buildings including many construction noise and vibration matters.

1.2 I am a director of the independent acoustic consultancy practice, Sandy Brown. Founded in 1969, Sandy Brown is one of the largest independent acoustic consultancies in the UK. Prior to joining Sandy Brown 18 years ago, I spent 11 years working for Sound Research Laboratories Limited advising on environmental noise and vibration matters. I have presented papers on acoustics at the Institute of Acoustics International Conferences. I am part of the British Council for Offices (BCO) Acoustics Working Group responsible for the BCO Guide for Specification. I was responsible for providing noise and vibration design advice as part of the design team that delivered the Medical Research Council Laboratory for Molecular Biology (LMB) building competed in 2013.

1.3 Some of my recent and relevant work includes:

a) Battersea Dogs and Cats Home (BDCH) in support of their objection to the TWAO for the Northern Line Extension which was to be located directly beneath the home. My advice specifically related to the construction methodology and the impact of noise and vibration during construction works.

b) In support of the Neighbourly Agreements for Nottingdale Village, I was appointed as joint expert supervising construction and demolition noise and vibration issues associated with this mixed-use scheme. This involved provision a noise and vibration monitoring regime and supervision of trials of various construction activities including piling and concrete breaking works.

c) Bankside Yards which is mixed used development comprising six high rise residential towers adjacent Blackfriars Station, London and this included detailed computer noise modelling of construction noise impacts for the Environmental Statement.

d) I was responsible for the design of vibration isolation for the St John's Wood Square which is a super prime residential development in London. It is to have vibration isolation included as part of the building foundations to protect against noise and vibration from the Jubilee Line.

e) Westfield, White City which included preparing the Environmental Statement and assessing the impact of noise from the road traffic and construction as consequence of the demolition of the Former Exhibition Building on residents in Shepherds Bush, London.

f) I was responsible for leading the acoustic design of the Walbrook building and the adjacent Bloomberg Headquarters building with architect Foster and Partners. As part of the design of the Walbrook Building in London, I was responsible for supervision of the construction vibration monitoring of St Stephens Church in relation to protection from structural damage due to construction activities.

g) I was responsible for the design of noise and vibration mitigation measures for the Broadgate Tower and 201 Bishopsgate office developments for British Land. Both of these buildings are situated directly above the platforms of Liverpool Street Station and both buildings incorporate anti-vibration measures to control vibration and ground borne noise from trains.

2 SCOPE OF EVIDENCE

2.1 I have been engaged by the MRC Laboratory of Molecular Biology (LMB) to advise on noise and vibration matters associated with The Network Rail (Cambridge South Infrastructure Enhancements) Order (CSIE). My evidence deals primarily with the works at Cambridge South station and the associated track works component as this is most relevant to the LMB.

2.2 My evidence is a review of the Environmental Statement (ES) and supporting information pertaining to noise and vibration prepared by Ramboll on behalf of Network Rail. My evidence will cover noise and vibration from the operation once completed and also temporary noise and vibration during construction. I have conducted baseline noise and vibration monitoring at the LMB to provide an independent baseline survey. Network Rail have provided supplementary technical updates of the ES relating to noise and vibration and I have considered this as part of my evidence. I have also attended meetings with Network Rail and their technical team to discuss noise and vibration matters.

2.3 I firstly described the current noise and vibration climate at the LMB and the sensitivity of the building to noise and vibration. My evidence will review the impact of operational vibration as reported in the ES which is a key area of concern. I also review the anticipated construction noise and vibration impacts from track works close to the site.

2.4 My instructions have been to review the ES and supporting documentation to assess the likely impact of noise and vibration and also to determine if the proposals will provide sufficient protection against excessive noise and vibration affecting sensitive equipment whilst protecting the welfare of the animals in the building. I will identify specific undertakings relating to construction methods, noise and vibration criteria and monitoring that will be required to mitigate the impact of noise and vibration during the construction phase and when the scheme is operational.

2.5 I provide a glossary of noise and vibration terminology in Appendix A1. I provide a list of figures at the end of the document in Appendix A2.

3 LMB BUILDING

3.1 The LMB ground floor and site layout is shown in Figure 1. The building has two laboratory blocks orientated approximately east-west connected by a full height atrium. The main external facade to the laboratory blocks is clad in an externally ventilated thermal flue. Areas of the western portion of the facade facing the railway do not have a thermal flue and are clad in double glazed curtain walling with opaque spandrel panels. The building's main mechanical plant is housed in a separate energy centre and in four stainless steel-clad towers linked to the building. This was a strategy developed to remove potential sources of vibration from the laboratory areas. There is an interstitial services zone between floors and all equipment serving the ground floor is supported from the first-floor slab to minimise vibration transfer to the ground floor.

3.2 The LMB contains equipment that is particularly sensitive to vibration specifically the electron cryo-microscopy unit (Cryo-EM) as well as other electron microscopes. In total, there are 14 electron microscopes located in the northeast wing of the building. One of the early design decisions was to locate the electron microscopes away from the railway in the northeast wing of the building to minimise the effect of vibration from the railway line. In addition, long term laboratory experiments (including in vivo testing using mice and fish) are conducted within the LMB that may be particularly sensitive to changes in the noise and vibration climate.

3.3 Vibration from the railway currently meets appropriate vibration criteria for electron microscopes and the LMB have advised that no increase in vibration would be acceptable. I set out below the relevant criteria which is determined by the resolution of the electron microscopes and any increase in vibration affects the resolution. Very low levels of vibration, well below the threshold of human perception, can disrupt this equipment in the form of adverse effects on sensing and positioning. It can also affect focusing of equipment and on the activities of the operators in performing these tasks.

3.4 The site is relatively quiet, and the main source of noise and vibration is the existing railway line adjacent to the site. The LMB building is located approximately 24 m west of the existing railway line and about 75 m north of the proposed station location. The Cryo EM laboratory is intentionally located in the northeast wing of the building approximately 180 m west of the railway. The ground floor of the building contains other laboratory areas with animals located in the northeast wing. There is a rodent holding room in the northwest wing of the building closest to the railway (see SH1/OBJ/9 for location plans). The LMB has external terraces at ground floor and roof level facing the railway where staff can relax. This area would be impacted by significant changes to the noise climate.

3.5 Passenger trains run on the existing tracks traveling north and south approximately every 2 minutes. These are up to 12 cars in length and travel at between 40 mph and 70 mph (the speed limit is 90mph). There are also occasional freight trains using the line which typically run about 1-2 per hour in both directions travelling at 45 mph each with a total capacity of 2400T.

3.6 As part of the original building design, Sandy Brown in collaboration with structural engineers AKT and the users at the MRC established suitable vibration design criteria. Due to the sensitivity of electron microscopes, the assessment of the impact of vibration is critical and strict vibration limits are required.

3.7 The basic units of vibration measurements relate to the movement of the surface that is vibrating which can be measured in units of velocity in metres per second (m/s). For small values, microns (µm) or millimetres (mm) may be used instead of metres (m). Vibration Criteria Curves (VC) are widely used for microelectronic facilities and have constant velocity over a defined frequency range (8 – 100 Hz). These are a set of curves referenced A-G with G having the lowest limit of 0.781 µm/s and A having the highest limit of 50 µm/s. The required limits at the LMB are VC-D for sensitive areas and VC-B for other areas 6.25 µm/s and 25 µm/s respectively. These limits are in line with accepted criteria detail in the Association of Noise Consultants (ANC) guidelines[1].

[1] Association of Noise Consultants: Measurement and assessment of Groundborne Noise and Vibration 3rd Edition 2020

3.8 The LMB have advised that electron microscope manufacturers specify floor vibrations of VC-F although this requirement can be reduced based on actual surveys conducted by the manufacturers to assess the site suitability prior to purchase and installation. At the design stage the MRC specified design criteria for the LMB based on maximum velocity levels of 25-50 µm/s which is equivalent to Vibration Criterion (VC) Curve B. The Cryo EM area of the LMB building was required to achieve VC-E with short term events of VC-D during train passes based on the manufacturer's specification.

3.9 During discussions the technical team at the LMB has indicated that no increase in vibration is desirable because this would potentially result in a loss of image resolution which in turn may impact on the performance of the Cryo EM.

3.10 The main operational impact is anticipated to be increased vibration because of the proposed switches and crossings to be installed close to the LMB. These switches and crossing will generate increased localised levels of vibration during train passes compared to straight lengths of track. The vibration from trains is generated by the interaction of the suspended bogie (i.e. axle and wheel assembly) with the track. The configuration of the switches and points introduces discontinuities in the track which results in an increase in vibration as the wheel crosses the gaps in the track.

3.11 The RIVAS 2013[2] report gives results from a study of complaints which showed that 32% were as a result of switches and crossings. In addition, the FTA[3] manual states: *"A large percentage of vibration impact from a new transit facility is often caused by wheel impacts at the special trackwork for turnouts and crossovers. When feasible, the most effective vibration control measure is to relocate the special trackwork to a less vibration-sensitive area."*

[2] Railway Indued Vibration Abatement Solutions Collaborative Project-SCP0-GA-2010-265754 Description of the vibration generation mechanism of turnouts and the development of cost-effective mitigation measures 29/3/2013.
[3] Federal Transit Administration Transit Noise and Vibration Impact Assessment Manual May 2006

3.12 There are also temporary construction noise and vibration impacts which include:

a) Works along the track close to the LMB and the construction of the station; and

b) Construction traffic using haul routes including access to the railway via the MRC car park.

3.13 The main construction impacts to the LMB are expected to be gantry works on the track close to the railway and the station works itself. The track works will take place to the west of the site and comprise three main activities:

a) Construction of a haul road to the west of the track;

b) Track works preparing the track; and

c) Overhead line works which involves creation of the overhead gantry.

3.14 Items a) and b) involve excavation, vibratory compaction and either laying the road surface or placement and tamping (flattening and levelling) of ballast. The haul road will be used by loaded lorries. Item c) involves piling at the gantry locations which will also involve compaction to prepare the ground for the piling. The main sources of vibration will be excavation, vibratory compaction and piling as well as fully laden lorries using the haul road.

3.15 There is also a proposal in the ES to provide a site access road along the south boundary of the LMB and a haul road along both the east and west side of the track. The site access road and east haul roads are potential sources of noise and vibration.

3.16 NR have requested access to the railway via the MRC car park for construction equipment including lorries, rollers and excavators. A consequence of this request is that lorry deliveries to the LMB would have to be rerouted to the northeast (ie most vibration sensitive area of the LMB) which would create an indirect vibration impact. NR have subsequently agreed to maintain delivery access to the LMB loading bay via the west route and for major construction traffic to use the haul road to the west of the railway with only occasional maintenance access via the LMB car park.

4 EXISTING NOISE AND VIBRATION CLIMATE

4.1 I conducted unattended baseline noise and vibration measurements in the LMB Building between 14 November 2021 and 19 November 2021. Vibration levels in the ground floor laboratory space were recorded close to the west of the building, and external noise levels at the roof terrace close the roof terrace outside the 5th floor restaurant continuously for 6 days. The monitoring locations are shown in Figure 1. This location was chosen because it is representative of the likely worst affected facade in terms of noise from the proposed station construction works. This noise monitoring location has a direct line of sight to the railway. Attended vibration measurements were also conducted in the building between 1200 hours and 1600 hours including 60 minutes of continuous vibration at the following two locations (as shown in Figure 1):

a) In Cryo EM laboratory in the northeast of the building; and

b) in laboratory space on the southwest side of the building close to the railway.

4.2 In determining overall vibration levels, it is normal to measure in 3 dimensions (i.e. vertically up and down, horizontally side to side and laterally front to back). These measurements were taken using an industry standard piece of equipment called an "triaxial accelerometer" in 3 perpendicular directions (x,y and z) with the z vertical axis being the most dominant axis of vibration.

4.3 The measured vibration levels during passenger train and freight train passes are currently lower than VC-D in the Cryo EM laboratory and lower than VC-B in laboratory areas elsewhere in the building which is within the originally specified vibration criteria.

4.4 The typical daytime ambient noise levels are in the region of L_{Aeq} 60 dB and the daytime background noise levels are in the region of L_{A90} 45 dB. The trains produce a short-term increase in noise as they pass. At the LMB west facade the maximum noise level during a train pass which lasts about 20 seconds is L_{AFmax} 80-85 dB. The summary of the results from the noise survey is shown in Figure 2. Construction noise impacts would normally be assessed in terms of L_{Aeq} over a 10-hour period and the L_{AFmax} would normally be used to assess short term transient events.

4.5 In summary, the LMB site is quiet, and the building facade is sealed and protects against existing noise sources. While the vibration is within the required criterion, the highest train events recorded are only just lower than VC-D at the Cryo EM. This means that there is no margin for any increase in vibration at the Cryo EM. In the other areas, vibration levels are within VC-C whereas the criterion is VC-B.

5 OPERATIONAL VIBRATION ASSESSMENT

Environmental Statement

5.1 Chapter 6 of the Environmental Statement (ES) deals with operational vibration, I have reviewed the vibration assessment in this section.

5.2 The ES makes reference to appropriate National Standards and Guidance although in section 6.2.4 states that due to the highly scientific nature of the work being undertaken a bespoke assessment process and assessment criteria has been adopted. This is because the above standards do not provide guidance on the acceptability limits for scientific equipment. The VC curves do not differentiate between continuous vibration or occasional transient vibration events such as trains. The bespoke approach to assess transient events is to use the maximum root mean square (RMS) vibration level during a train pass. RMS is a form of averaging over the duration of the event which is consistent with the approach used to assess the LMB originally and I consider this to be a reasonable basis for assessment.

5.3 The LMB is identified as being high sensitivity receptor due to the low vibration requirements of the Cryo EM laboratory.

5.4 Baseline vibration levels are detailed in the ES and the two locations agreed with the LMB. These locations were also used for my baseline measurements. The vibration assessment is based on individual train events rather than the total numbers of trains noting the timetable changes are detailed in Appendix 5.2 of the ES. This is because the short-term vibration during a train event is the main consideration. The vibration level from individual train events will be determined by:

c) Train type (passenger or freight);
d) No of coaches;
e) Direction (north or south); and
f) Speed (up to 90 mph).

5.5 The bespoke assessment methodology has been adopted to assess vibration changes due to the switches and crossings and has been done by comparative measurements at the Shepreth Branch Junction which is 2km south of the proposed station.

5.6 The assessment compares the vibration levels taken close to the switch and crossing with a straight length of track and correcting these results for distance. This type of assessment relies on similarity between the Shepreth Branch Junction in terms of switch and crossing design, track geometry, train speed and ground conditions. The train speed and ground conditions at Shepreth are similar to that of the LMB. However, the switches crossing and geometry at the Shepreth branch are not the same as those proposed to be located close to the LMB.

5.7 The Shepreth Branch track has a turnout radius of 300 m which is smaller than the proposed switch and crossing at the LMB which has a radius of 1,200 m and therefore the assessment is not based on a similar situation. I would expect impacts arising from the tighter radius to be greater all things being equal. This is based on the RIVAS 2013 report which investigated differences in amplification with different turnout radii and concluded that the smaller the turnout radius the higher the amplification.

5.8 The assessment of vibration impact in the ES is based on changes in VC bands. Each band represents a doubling of vibration level (for example, a doubling of vibration amplitude from 25 µm/s to 50 µm/s would be change from VC-B to VC-A).

5.9 In the ES, any increase in vibration is considered a minor impact and a change in vibration band is classed as a major impact. For high sensitivity receptors a minor, moderate, or major impact is classed as having a significant adverse impact.

5.10 The ES lists out assumptions in the assessment and the following are noted:

a) The ES is based on 12 freight trains and 367 passenger trains per day;
b) No change in running speed of trains at the LMB;
c) Introduction of switches and crossings;
d) Assessment on single train events at any one time;
e) No change in rail/wheel roughness and track conditions; and
f) Maintenance will keep the track in good condition.

5.11 The main vibration impact at the LMB will be due to c) introduction of switches and crossings on the eastern track which is closest to the LMB. The NR planning drawings show the switch directly adjacent to the LMB.

5.12 The ES reports the baseline vibration results in Appendix 6.1 which indicate vibration levels lower than VC-D at the Cryo EM laboratory and lower than VC-C at the west of the building. This is consistent with the findings from my measurements and also consistent with the baseline measurements taken in 2006. My measurements are summarised in Figure 3.

5.13 Appendix 6.3 details the assessment of the effect of switches and crossings. This is assessed by applying an amplification factor to account for the increase in vibration from the switches and crossings and to apply a correction for distance from the switch and crossing to the LMB. The amplification factor has been determined by a comparison of measurements taken at Shepreth Junction with another section of straight track at similar distance located 500m away from Shepreth Junction. These comparative measurements indicate a sevenfold increase in vibration amplitude.

5.14 The assessment of Shepreth Junction does not provide any detail of the speed and length of the trains recorded, nor whether this assessment included the effect of freight trains.

5.15 The amplification factor from the ES is shown in Figure 4. The modified vibration levels have been corrected for distance to the LMB building. The revised predicted vibration levels at the LMB from the ES are given in Figure 5 . This shows an increase in vibration from VC-D to VC-B at location 1 (Cryo EM) and from VC-C to VC-B at location 2 (west wing laboratory). This increase is assessed as significant requiring further unspecified mitigation measures which could include modification to the crossing geometry and track supports or vibration isolation tables for the sensitive equipment in the LMB.

5.16 Section 6.4.12 of the ES lists mitigation principles included in the embedded design and the third bullet point states: *"The new switches and crossings are positioned away from sensitive buildings where possible".*

5.17 Under 6.4.15, the ES states that for the LMB a residual impact is predicted requiring further mitigation. This understates the predicted impact. The predicted residual impact is an increase in vibration of 2 VC bands from VC-D to VC-B which is classed in the ES as a major impact for a high sensitivity receptor resulting in a significant vibration impact (it is a major increase to move between bands and here there is a two-band difference).

5.18 Further mitigation options at the railway are listed in Table 6.13, although many of the options are then identified as not being expected to be suitable. These measures include the following:

a) Resilient fasteners: the ES states that this is not expected to be suitable but should be reviewed further;
b) Ballast mats: the ES states that this not expected to be suitable;
c) Floating slab track: the ES states that this may be suitable;
d) Resiliently supported ties: the ES states that this may be suitable;
e) Switch and crossing design and optimisation: the ES states that this has been assessed and found not to be feasible given the site constraints; and
f) Move the switches and crossing further away: the ES states that this is limited by the Long Bridge Road.

5.19 The ES suggests provision of mitigation measures at the receptor in the form of active vibration isolation systems for the electron microscopes and other sensitive equipment. This involves provision of specialist tables that have either air springs or active vibration isolation systems which act like shock absorbers in a car. It is not clear that such mitigation would be appropriate and the LMB team have reservations about the effectiveness of such systems.

5.20 In summary, the ES has identified a significant increase in vibration caused by the introduction of switches and crossings close to the LMB. No specific mitigation measures are identified in the ES and while a significant adverse impact is predicted, and mitigation is being explored, this is unclear and unspecified. The ES concludes that the residual effect is no longer significant.

5.21 In conclusion, the assessment method of operational vibration and baseline measurements are reasonable although I consider that the ES does not adequately address the predicted adverse vibration impact and is inconclusive over the effectiveness of any mitigation measures.

Ramboll Technical Update Note 5

5.22 Ramboll provided an update to the ES dated 14 October 2021 which provides further detail on the bespoke assessment and proposed mitigation of railway vibration to the LMB. This describes an option considered to move the switch and crossing away from the LMB at least 200 m north of the LMB. NR have advised that this was rejected as it would have had major impacts on the operation of the guided busway serving the CBC. It is not for me to comment on this point. Other mitigation options are proposed which include:

a) Refinement of propagation model (*this is not actually a mitigation option*);
b) Geometry optimisation;
c) Crossing design;
d) Under rail pads;
e) Under sleeper pads; and
f) Earthwork interlayers.

5.23 The technical update considers the RIVAS 2013 research paper[4] which provides supporting research that indicates that amplification factor measured at Shepreth Junction is pessimistic. This is mainly because the geometry in terms of the turnout radius is much tighter at Shepreth Junction (300 m) than that proposed (1,200 m). The refinement of the amplification factor has reduced the amplification factor from 7 to about 2 which is a significant change.

[4] Railway Indued Vibration Abatement Solutions Collaborative Project-SCP0-GA-2010-265754 Description of the vibration generation mechanism of turnouts and the development of cost-effective mitigation measures 29/3/2013.

5.24 The RIVAS research paper referred to in the assessment does conclude that based on mean measurements there is a relationship between vibration amplification and geometry including turnout radius. However, there is still high variability in this data as can be seen from data from the same paper (but on the previous page) shown in Figure 6. Reviewing this data, I also note that some measurements of 1,600m radius turnout resulted in an amplification factor of 5. This paper also indicates that geometry, ground conditions and maintenance status have a strong influence on turnout amplification and the paper quotes differences of a factor of 3, or higher, can occur. The paper also suggests that the amplification factor is dependent on speed and increases by a factor of 3 from 25 mph to 50 mph. The revised single point source propagation is reasonable but needs to be verified by synchronised measurements at varying distances from the points which has subsequently been carried out by Ramboll (see next section).

5.25 The revised amplification factors and propagation model has resulted in a revised assessment. This indicates vibration from freight trains will be within VC-C in the Cryo EM laboratory which is still above the required criterion of VC-D. It also notes that the passenger trains are now estimated to be within VC-D.

5.26 Following this update, there remains a high degree of uncertainty associated with the assumed amplification factor and therefore a high degree of risk of increased vibration in the Cryo EM laboratory. This is clearly shown when it is considered that the RIVAS report shows that some measurements of 1,600m radius turnout resulted in an amplification factor of 5 whereas here the amplification factor used by Network Rail is 2 based on a shorter radius which would point towards a higher amplification factor, not lower. This RIVAS report also shows a high degree of variability in the results (see extract in Figure 6). I say this to express the levels of uncertainty inherent in the Network Rail work rather than to say it is wrong.

5.27 In summary, the revised assessment detailed in the technical update predicts that the introduction of switches and crossing will still exceed the required criterion. There is a high degree of uncertainty with the assessment and prediction noting there is no margin for any increase in vibration. Therefore, the conclusion remains that the switches and crossing represent a significant (major) impact based on the change from VC-D to VC-C and the risk to the LMB that vibration levels may increase remains.

Ramboll Feedback to MRC LMB 11 November 2021

5.28 Following on from the technical update, Ramboll presented the results from an additional vibration survey of switches and crossings on the 11 November 2021 to myself and the LMB team.

5.29 This is a similar bespoke assessment to that conducted as a part of the ES although the new switches and crossings measurement location is considered to be more representative than Shepreth Junction used in the ES because it has a larger turnout radius of 600 m. The proposed switches and crossing turnout radius is 1,200 m.

5.30 This assessment concentrates on comparing southbound trains without switches and crossings, with northbound trains with switches and crossings, and has limited the assessment to two pairs of trains at similar speeds and lengths. The speeds considered are 45 mph and 60 mph. The measured vibration levels for the first pair of trains close to the track indicates an increase in vibration from 40 µm/s to 100 µm/s (60 mph/12 car) at 40 Hz corresponding to an amplification factor of 2.5. The measured levels for the second pair indicate an increase in vibration from 30 µm/s to 100 µm/s at 40 Hz (45 mph/8 car) corresponding to an amplification factor of 4.

5.31 The measurements further away from the track demonstrate that the amplification effect is much reduced with distance and the measurements at 160 m from the track indicate that passenger trains are within VC-D and freight trains are marginally above VC-D.

5.32 I would expect that there will be a further reduction in vibration from measurements in the ground to measurements on the ground floor of the building (a coupling loss). The coupling loss is the difference between measurements in the ground and measurements on the floor slab of the building and represents the attenuation of vibration through the building foundations. Accounting for this loss then this indicates that required criterion will be met.

5.33 I consider the revised updated assessment to be more robust than the original ES assessment which now indicates that the required criteria will be met and I make the following observations:

a) The measurements were taken west of the points which were located on the opposite side of the track to the measurement position. The new points are to be located on the southbound track closest to the LMB. Measurements taken at an equivalent distance directly adjacent to the track on the opposite side may yield higher results;
b) The amplification factor is not based on freight train events;
c) The condition of the points and similarity of design of those measured to those proposed is not known; and
d) It is possible that vibration may propagate more easily within the building structure than within the ground. Therefore, vibration entering the building at the closest point may not attenuate at the same rate as vibration in the ground. In other words, the attenuation with distance may be lower than assumed.

5.34 The measurement summary also provides a comparison of vibration time histories in the Cryo EM laboratory. This confirms that the main source of vibration measured in Cryo EM laboratory is train events and that these are generally within VC-D. The vibration events due to trains in the time history suggest only 6 vibration events between 11:30 and 13:30 whereas the timetable in Appendix 5.3 suggests there would be 42 trains events in both directions.

5.35 This would indicate that the time history has not identified all of the train events. Nevertheless, the time history confirms that non train vibration events are up to 5 μm/s which is within the required VC-D.

5.36 In conclusion, the measurement updates indicate that the switches and crossings are now predicted to be within VC-D and that existing sources of vibration are also within VC-D. However, as I have indicated there is a high degree of uncertainty in relation to the amplification factor and therefore the predicted levels based on the difference between the switches used for the measurement and those proposed which represents a residual risk to LMB.

5.37 NR should be required to provide assurances that the VC-D curve will not be breached, and the monitoring of vibration will be provided to verify this with periodic updates to confirm that there has not been any deterioration in track and joint conditions over time. In addition, the track geometry will need to be confirmed as suitably similar to that used in the assessment. These noise and vibration limits are recommended to form part of the undertakings to be provided by NR.

6 CONSTRUCTION VIBRATION

6.1 The construction vibration assessment is provided in Appendix 6.2 of the ES. The main impacts to the LMB are expected to be gantry works on the track close to the railway and the station works itself.

6.2 The track works will take place to the west of the site about 25 m from the closest point to the LMB. The track works comprise three main activities:

a) Construction of a haul road to the west of the track;

b) Track works preparing the track; and

c) Overhead line works which involves creation of the overhead gantry.

6.3 Items a) and b) which involve excavation, vibratory compaction and either laying the road surface or placement and tamping (flattening and levelling) of ballast. The haul road will be used by loaded lorries. Item c) involves piling at the gantry locations which will also involve compaction to prepare the ground for the piling. The main sources of vibration will be excavation, vibratory compaction and piling as well as fully laden lorries using the haul road.

6.4 There is also a proposal in the ES to provide a site access road along the south boundary of the LMB and a haul road along both the east and west side of the track. The site access road and east haul road are close to the LMB and are potential sources of noise and vibration.

6.5 The station works take place further away but involve similar vibration producing activities to the track works and for a longer period of time.

6.6 The assessment of construction vibration follows BS5228[5] and is assessed in terms of peak particle velocity (PPV) and the vibration impact criteria is based on BS5228 guidance for human vibration. Under 6.2.59, the ES states that impact classification take account of the enhanced sensitivity of the receptors and have been set lower than would be applied for human perception. The threshold of human perception is PPV 0.14 mm/s if this was to be compared with operational vibration then the rms velocity would be used which would be approximately 0.707 times lower (assuming a sine wave). A limit of PPV 0.14 mm/s is approximately 0.09 mm/s (90µm/s) which can be compared with VC-A which is equivalent to 50µm/s.

6.7 In addition, the vibration assessment considers the Vibration Dose Value (VDV). This is used to assess human response to vibration and significance is defined in accordance with accepted procedures and classifying a significant impact at VDVs of 0.4 $ms^{-1.75}$ during the day and 0.2 $ms^{-1.75}$ during the night. The significance matrix on page 6-10 of the ES suggests construction vibration will only be significant at levels classed as having a minor impact which is defined as less than 0.14 mm/s. This implies that temporary construction vibration at VC-A would be the onset of significance.

6.8 In section 6.2.1, the ES states "The station zone is expected to have a longer period of construction work associated with it whilst the areas with track works will be shorter, with the most intense works limited to discrete track possessions".

6.9 The ES advises that the anticipated vibration producing construction activities are as follows:

a) Vibratory compaction by means of vibratory roller
b) Large bulldozer excavation and/or transport of material
c) Loaded trucks with loading and unloading operations
d) 360-degree excavators
e) Vibratory piling (see below)
f) Rotary bored piling.

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[5] BS5228-2:2009+A1:2014 Code of Practice for noise and vibration control on construction and open sites – part 2 Vibration.

6.10 The ES states that vibratory piling works are to be avoided wherever possible and will not be used except for the OLE works at Shepreth Branch Junction where they may be required due to limited time periods for track possessions. In relation to the LMB, the ES states that it is unlikely that these buildings will achieve their low vibration requirements whilst some elements of construction activity are in progress, even for construction activities that have only negligible impact to human response.

6.11 In this case, it is then important that mitigation measures are taken, which may include:

a) Informing the occupants of the building of the schedule of works with particular attention to activities of extended duration that are close to the sensitive receptors;
b) Appropriately prepare the surface of the site access and site haul roads in order to minimise the induced vibration from loaded trucks and vehicles going past;
c) Vibratory methods (e.g., vibration compaction and vibratory piling) to be avoided except in specific time windows where notice has been given to nearby receptors; and
d) Agree a time schedule with the building occupants for the access of large vehicles in areas particularly close to buildings (i.e., site haul road at west of the MRC LMB building).

6.12 The assessment is provided in Table 6.2.5 of the ES and this lists vibration impacts at the LMB as follows:

a) Site Haul Road PPV 1.16 mm/s VDV 0.66 $ms^{-1.75}$
b) Track works PPV 4.49 mm/s VDV 2.54 $ms^{-1.75}$
c) Guided busway PPV 1.5 mm/s VDV 0.85 $ms^{-1.75}$
d) Site access road PPV 0.11 mm/s VDV 0.06 $ms^{-1.75}$

6.13 Moderate impacts are predicted at the LMB building which results in a significant effect in accordance with the Significance Matrix. The ES concludes a significant impact of construction vibration. The ES states for the LMB, the closest works are the creation and use of the haul roads. Construction of these haul roads will be of short-term duration. A well-maintained road surface will be provided to mitigate against any increase in vibration impacts due to potholes and other significant vibration causing defects.

6.14 Construction vibration monitoring is proposed to alert the contractor to any exceedances of defined criteria, allowing the contractor to take steps to mitigate the exceedances. The protocols for alarms and alerts will need to be clearly set out and agreed to avoid unnecessary breaches of the agreed vibration limits. This requires a proactive approach from the contractor. In section 6.5.5, it is acknowledged that close proximity of some of the construction works will lead to difficulty in mitigating the adverse effects of construction vibration and the residual impact remains significant.

6.15 In conclusion, the ES predicts significant impact from vibration due to construction activities which cannot be fully mitigated although the precise construction methodology and duration of the various impacts is not clear in the ES.

Ramboll Technical Update Note 5

6.16 Ramboll provided an update to the ES dated 14 October 2021 which provides further detail on the assessment and proposed mitigation of construction vibration to the LMB.

6.17 This note states that from the stakeholder engagement meeting, if the proposed mitigation measures are implemented, the main concern for the LMB in relation to construction vibration impact is indirect. This indirect effect is that their vehicular deliveries may be prevented from passing to the west of the building and instead would need to pass to the east and immediately adjacent to their most vibration sensitive areas of the building.

6.18 Network Rail have confirmed that access to the west of the building would be maintained for the LMB to use and that they would not need to change their vehicular routes. A traffic management plan would be in place to control this. The following additional mitigation steps are being planned to further reduce the construction vibration impacts:

a) Subject to confirmation, the construction haul road through the LMB site is to be removed or its use kept to a minimum as alternative construction routes have been identified

b) Major construction traffic would use the haul road to the west of the railway line and, specifically, earthworks traffic would use that route. However, NR have retained the option to use the roads closest to the LMB which will have a greater vibration impact than the current assessment.

6.19 In the meetings with NR and Ramboll, Ramboll have agreed to provide a more detailed construction vibration assessment of potential track works combined with durations of activities to enable LMB to fully assess the likely impact of vibration during the construction works. This has been provided in Technical Update Note 10 discussed below.

Ramboll Technical Update Note 10

6.20 Ramboll provided a further update in Technical Note 10 dated 3 December 2012 which revisits the assessment and provides further details of the assessment and supporting information with regard to the main vibration producing activities specifically vibratory compactors, piling, vibratory roller, bulldozer, loaded trucks and 360-degree excavation.

6.21 The assessment details predicted levels at the LMB and the revised prediction now predicts vibration levels all within VC-B at a distance of 70m from the track works and generally within VC-D at 175m from the track works (i.e. at the Cryo Em). The only exceedance of VC-D is for the vibratory roller (which appears to be reported in error in in/s rather than mm/s and under reports the impact which is 0.09 mm/s i.e. VC-C) and vibratory compaction start up and run down and the predicted level is 0.05 mm/s which is just above VC-D which is approximately PPV 0.044 mm/s. The conclusion recognises this and advises controlled start up and run down is necessary to avoid exceedance of VC-D. Control of the vibratory roller operation is also required based on the corrected level of 0.09 mm/s reported above.

6.22 These revised predictions are significantly lower than those reported in the ES (see 4.11 above) and are predicted to be generally within acceptable levels. Vibration monitoring is proposed to enable management of vibration levels from track works close to the LMB.

6.23 It is noted that the updated assessment assumes that all track access will be from the haul road to the west of the track and that the access and haul road to the east of the track will not be used. However, NR have retained the option to use these roads closest to the LMB which will have a greater vibration impact than the current assessment.

7 OPERATIONAL NOISE ASSESSMENT

7.1 Chapter 5 of the Environmental Statement deals with noise, and I review operational noise in this section.

7.2 The ES defines the LMB as highly sensitive to noise and the main noise source at the site is railway noise. This has been assessed in accordance with the Calculation of Railway Noise[6] (CRN) using computer modelling CadnaA which is an industry standard software package.

7.3 The magnitude of impact uses the noise change based on the principles defined in the Design Manual for Roads and Bridges[7] (DMRB).

7.4 The operational rail noise is predicted to reduce by 2.8 dBA at the LMB and Ramboll have confirmed that this is a consequence of the reduction in speed for a number of passenger trains combined with changes in the number of coaches as detailed in Table 3 of Appendix 5.2.

7.5 The changes in road traffic are detailed in Appendix 5.2 and there is a 6% increase in vehicles with the development which would results in a change in noise level of about 0.2 dB which is negligible.

7.6 The ES concludes that operational noise from rail, road and fixed plant are not significant. The assessment appears reasonable and there is no significant impact on the LMB building.

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[6] Calculation or Railway Noise Technical Memorandum 1995

[7] Design Manual for Roads and Bridges Volume 11 Section 2 Environmental Assessment Techniques Part 7 Nosie and Vibration November 2011

8 CONSTRUCTION NOISE ASSESSMENT

8.1 The ES follows accepted assessment methodology as defined in B5228-1[8] which is the relevant standard used for the assessment of construction noise.

8.2 The sensitivity of the LMB is defined as very high in the ES. Minor, moderate, and major impacts as defined by the Sensitivity Matrix from the ES and are classed as significant.

8.3 I noted that the ES and subsequent assessments have not considered the external terraces used for rest and relaxation by the staff in the assessment.

8.4 BS5228 provides two methods of assessing potential significance based upon noise change i) the ABC method and ii) the 2-5 dB(A) change method. The ABC method was adopted for the ES. The ABC method involves measuring the ambient noise levels at the receptor location and assigning a category for the site based on the ambient noise levels. Each category has noise thresholds defined for the daytime (07:00 – 19:00), evening (19:00- 23:00) and night (23:00-07:00). Category A is used when ambient noise levels are relatively low, Category C is used when ambient noise levels are relatively high. The daytime thresholds in terms of $L_{Aeq10hr}$ are 65 dB for Category A, 70 dB for Category B and 75 dB for Category C.

8.5 In terms of construction noise, the ES defines a moderate impact when the relative threshold value is exceeded by up to < 5 dB. A major impact is predicted when the construction noise is ≥ 5 dB above the threshold value.

8.6 The measured daytime L_{Aeq} noise level at the LMB is 59 - 62 dB which places the site in Category A which has a threshold value of L_{Aeq} 65 dB. The predicted construction noise level from the ES is L_{Aeq} 72 dB which is 7 dB above the threshold. Therefore, construction noise is assessed as a major impact which is a very large effect and considered significant.

[8] BS 5228-1:2009+A1:2014 Code of practice for noise and vibration control on construction and open sites

8.7 The measured night-time L_{Aeq} noise level is 58-59 dB which places the site in Category C which has a threshold value of 55 dB. The predicted construction noise is L_{Aeq} 55 dB which is lower than the measured ambient noise level. This is assessed in the ES as minor (this appears incorrect in the ES). Based on the assessment method this should be a negligible impact which is not significant as reported in the summary of the ES.

8.8 The predicted daytime construction noise impacts are estimated to be mitigated by 5 dB(A) when adopting Best Practicable Means (BPM) as defined in the Code of Construction Practice. However, the mitigation assumptions are very generalised and should be scrutinised to determine if they are, in fact, practicable. A residual impact after mitigation reduces from very large to moderate for the daytime construction noise. The construction noise calculations are provided in Appendix 5.3 of the ES although the calculation appears to be very simplistic and lacks clarity regarding to the predicted impact at the LMB. I have subsequently discussed this assessment with Mr Simon Taylor of Ramboll who advises that all of the station works will be behind a site hoarding which provides noise screening. The screening benefit of the hoarding depends on the relationship between the height of the noise source and receptor in relation to the hoarding.

Ramboll Technical Note 14 October and update note MRC-AC2 2 December 2012

8.9 Ramboll provided a technical response dated 14 October 2021 which provides some further detail on the construction activities but does not provide any further information of the proposed construction works at the station. The note does however provide an indication of the noisiest activities from the track works. The assessment assumes that the noisiest activity will be concrete breaking associated with dressing the piles. The sound power level is given as 120 dB(A) and based on the corrections provided with this calculation, this would result in an L_{Aeq} of 79 dB at the MRC. The daytime threshold is $L_{Aeq10hr}$ 65 dB and so will be exceeded.

8.10 The assessment has been updated on the 2 December 2021 and the general construction activities are predicted to be $L_{Aeq10hr}$ 67 dB which is classed in the ES as a moderate impact. In the ES a moderate impact for a high sensitivity receptor is classed as significant using the ES methodology. Ramboll advise that the predicted level is a reasonable worst case.

8.11 Ramboll have also assessed the L_{AFmax} levels and predicts levels incident on the west façade of 74 dB for general activities and maximum levels of 86 dB during breaking out of pile caps. The report advises that the breaking out works will be limited to 4 hours per foundation for the two closest foundations to the LMB.

8.12 The comparison with the worst case baseline L_{AFmax} is also not accurate because this is the maximum level over a 10-hour period and therefore it does not occur regularly. My noise measurements show the $L_{AFmax,15min}$ levels is generally less than 85 dB. Therefore, the assessment is not robust. Based on my experience of the LMB, the actual external facade performance is in the region of $R_w + C_{tr}$ 35 dB and a target internal noise level of L_{AFmax} 55 dB ($L_{Aeq5min}$ 45 dB) from regularly occurring construction activities, this would suggest the external noise levels must not exceed 80 dB(A). To avoid confusion with train events a short term $L_{Aeq15min}$ of 75 dB is proposed as an operational noise limit.

8.13 The Housing of Care of Animals used in Scientific Procedures under section 2.6[9] refers to a general background sound level of below 50 dB(A) as being a level where it is unlikely there will be damage to animals or personnel. This is assumed to be an L_{Aeq} level and would be achieved if external noise levels are within L_{Aeq} 75 dB.

8.14 In terms of construction traffic, it is unclear in the ES how the impact of these roads has been assessed. Section 5.2.18 indicates that haul roads are included in the assessment, but this is not clear from the Appendix how the access road and haul road contributions have been assessed and the anticipated maximum number of vehicles per day on these routes. The ES suggests 50 vehicles per day in section 4.3.42 which will be 8-wheel large 20T trucks. This information is still to be provided.

8.15 In summary, it is anticipated that the construction impacts from the station works will be reduced to acceptable limits by virtue of distance although the assessment in provided as part of the ES is overly simplified. In my meetings with NR, the duration of the track works has been advised to be in the region of 7 weeks and so will be of relatively short duration. External noise monitoring is recommended during the track works with short term limits of $L_{Aeq15min}$ 75 dB as well as daily limits of $L_{Aeq10hr}$ 70 dB.

9 CONCLUSION

9.1 I have conducted a detailed review of the ES for The Network Rail (Cambridge South Infrastructure Enhancements) Order (CSIE).

9.2 I have conducted baseline noise and vibration measurements at the site which are consistent with the levels presented in the Environmental Statement (ES).

9.3 Due to the sensitivity of electron microscopes, the assessment of the impact of vibration is critical and strict vibration limits are required. The main impact in terms of vibration is a consequence of the proposed switches and crossing which will generate increased localised levels of vibration. However, as I have indicated there is a high degree of uncertainty in relation to the amplification factor and therefore the predicted levels based on the difference between the switches used for the measurement and those proposed which represents a residual risk to LMB.

9.4 NR should be required to provide assurances that the VC-D curve will not be breached, and the monitoring of vibration will be provided to verify this combined with periodic updates to confirm that there has not been any deterioration in track and joint conditions over time. In addition, the track geometry will need to be confirmed as suitable. These noise and vibration limits are recommended to form part of the undertakings to be provided by NR.

9.5 Construction noise and vibration is assessed in the ES to have a significant impact during daytime works and Best Practicable Means (BPM) are be adopted to mitigate noise. I expect that the station works are likely to be adequately controlled and whilst the track works are of limited duration short term significant impacts are predicted during these works. Noise and vibration limits combined with monitoring during the construction periods is recommended.

[9] HMSO Home Office Code of practice for the Housing and Care of Animals used in Scientific Procedures 1989

10 WITNESS DECLARATION AND STATEMENT OF TRUTH

I hereby declare as follows:

This proof of evidence includes all facts which I regard as being relevant to the opinions that I have expressed and that the inquiry's attention has been drawn to any matter which would affect the validity of that opinion.

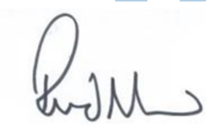
I confirm that I am not instructed under any conditional or other success-based fee arrangement.

I confirm that I have no conflicts of interest.

I believe the facts that I have stated in this proof of evidence are true and that the opinions I have expressed are correct; and

I understand my duty to the inquiry to help it with matters within my expertise and I have complied with that duty which overrides any obligation to those instructing or paying me. I have prepared my report impartially and objectively, and that I will continue to comply with that duty throughout these proceedings.

I confirm that I have made clear which facts and matters referred to in this report are within my own knowledge and which are not. Those that are within my own knowledge I confirm to be true. The opinions I have expressed represent my true and complete professional opinions on the matters to which they refer.



Digitally signed by Richard Muir
Reason: I am the author of this document
Contact Info: richard.muir@sandybrown.com
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Richard Muir

Sandy Brown Limited **5 January 2022**

A1 APPENDIX ACOUSTIC TERMINOLGY

10.1 Sound or noise levels are commonly measured in terms of the sound pressure level in decibels (dB). A decibel or logarithmic scale is used because it provides a convenient scale that follows the human sensitivity to the amplitude of sound. The human threshold of audibility is about 10 dB, and the human threshold of pain is about 120 dB.

10.2 Noise can also be defined in terms of its frequency or pitch which measured in Hertz, (Hz). The human audible range is from 20 Hz up to 20 kHz. The human ear sensitivity to noise varies with frequency and is more sensitive to mid to high frequency sound than it is to low frequency sound. Noise is normally measured with a frequency weighting called the A-weighting written as dB(A). The A weighted sound level, or dB(A), is used because it closely resembles the frequency response of the human ear and has been found to correlate well with the human subjective response to noise. A sound level of less than 20 dB(A) is virtual silence, 30 dB(A) is quiet, 50 dB(A) is a moderate noise level, 70 dB(A) is quite noisy and at about 90 dB(A) normal speech is difficult. Figure 6 gives some examples of typical sound levels.

10.3 The frequency range can be divided into bands covering a specific range of frequencies. A scale of octave bands and one-third octave bands is normally used. A band is said to be an octave in width when the upper band frequency is twice the lower band frequency. Frequency analysis of sound is normally conducted in octave (1/1) or one third (1/3) octave bands. I will refer to frequency bands in the when assessing the tonality of noise.

10.4 For time varying noise, it is normal to use an energy average called the A weighted equivalent continuous sound level, or the $L_{Aeq,T}$ level, over a defined time period, T. The $L_{Aeq,T}$ is the constant A weighted noise level that would contain the same A weighted acoustic energy as a time varying signal. This enables the noise to be described by a single number.

10.5 The $L_{AFmax,}$ or $L_{ASmax,}$ is the maximum A weighted sound level over a measurement period with either a fast (F) or slow (S) time constant. The fast or slow response is used to smooth out instantaneous transient fluctuations in the sound level. The L_{Amax} level is often used to characterise peaks such as transient sounds and the bass beat in music.

10.6 The background noise level is often defined as the A–weighted level that is exceeded for 90% of the measurement period and is denoted the L_{A90} noise level.

10.7 In my evidence the term ‘vibration' is restricted to displacement of the ground or of structures due to the propagation of waves through the ground.

10.8 The basic units of vibration measurements relate to the movement of the surface that is vibrating. This can be measured either in units of velocity in metres per second (m/s) or of acceleration in metres per second per second (m/s^2). For small values, microns or millimetres may be used instead of metres.

10.9 The decibel scale is sometimes used for the measurement of vibration as well as of noise, and for example, when velocity is measured in decibels above a reference level of 1µm/s metre then a velocity level of 120 dB is 1 millimetre per second (1 mm/s).

10.10 Vibration Criteria Curves (VC) are widely used for microelectronic facilities with constant velocity in the range 8 Hz – 100 Hz.

A2 LIST OF FIGURES

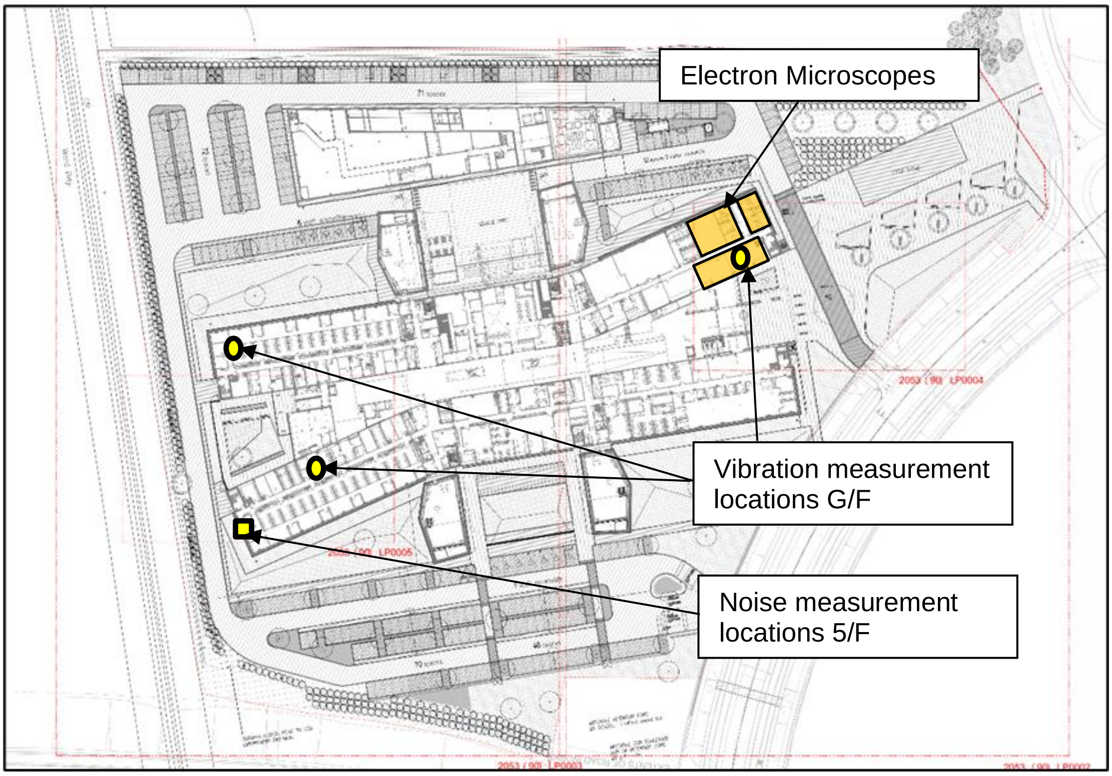

Figure 1 LMB Building ground floor

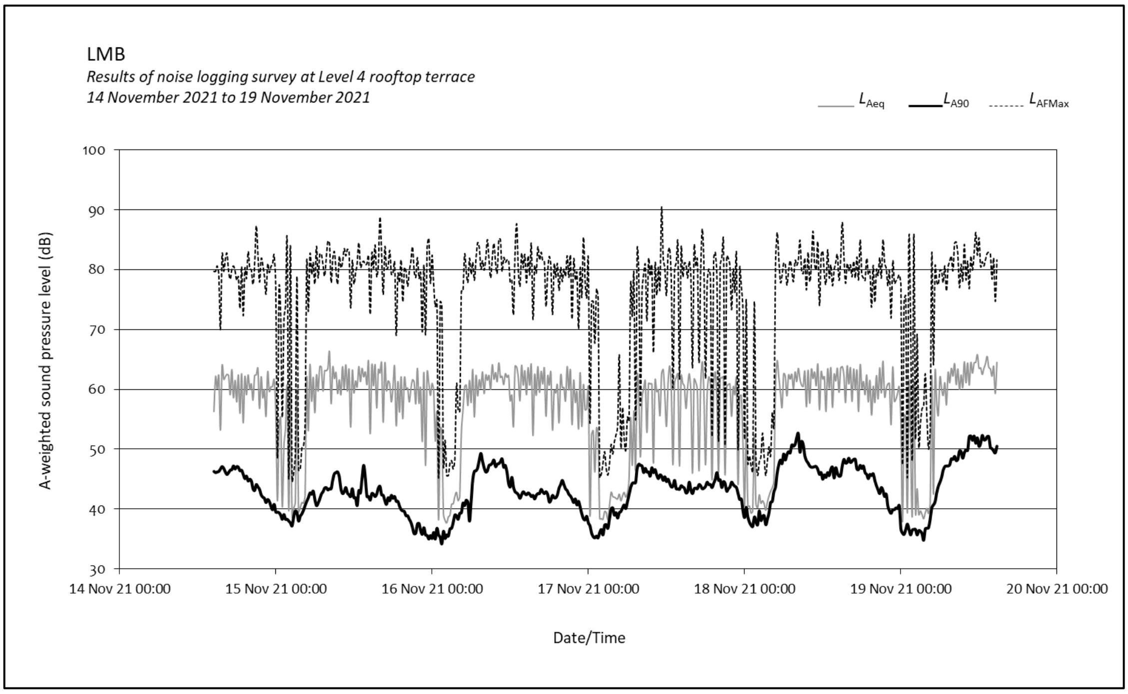

Figure 2 Baseline noise levels

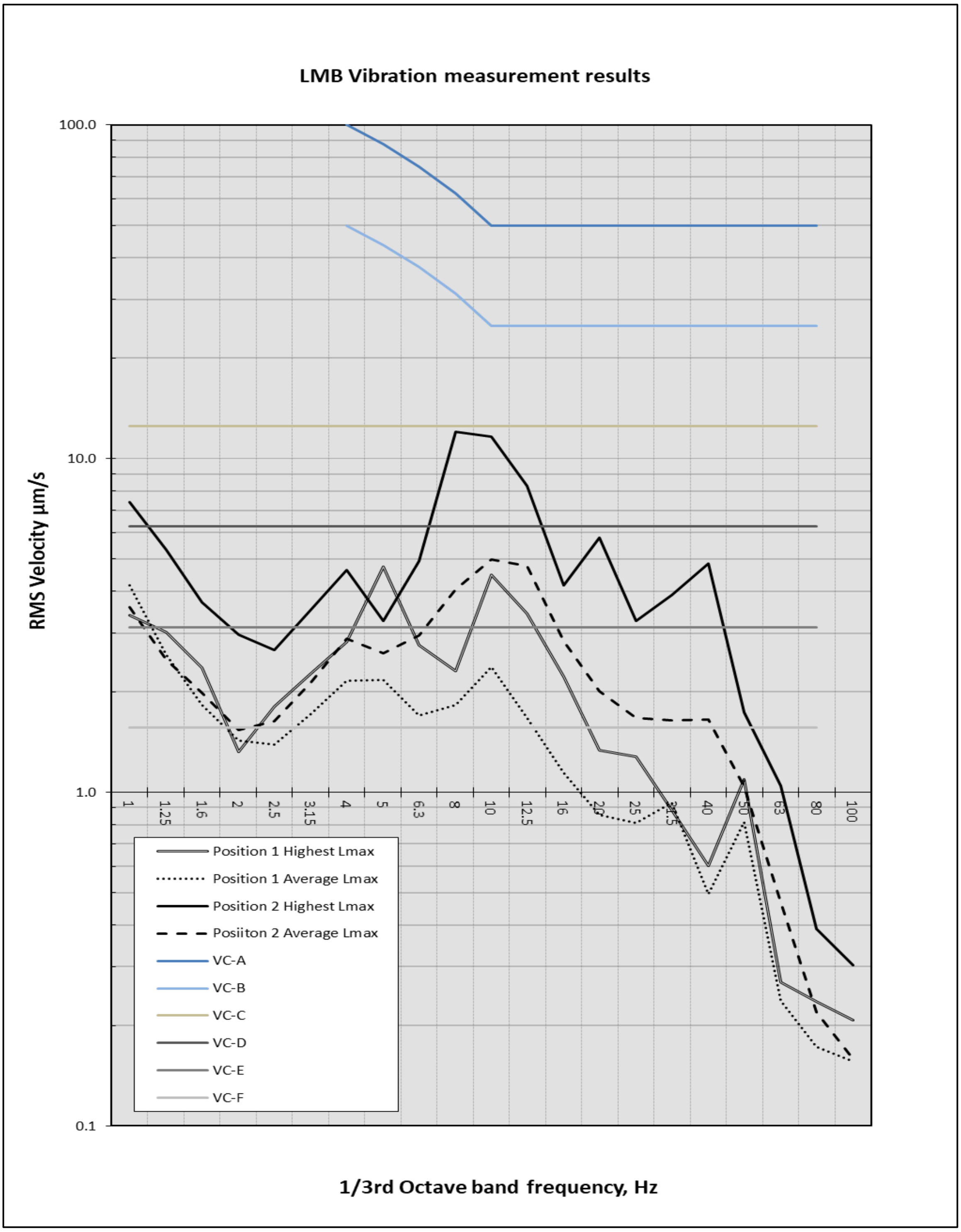

Figure 3 Baseline vibration measurements

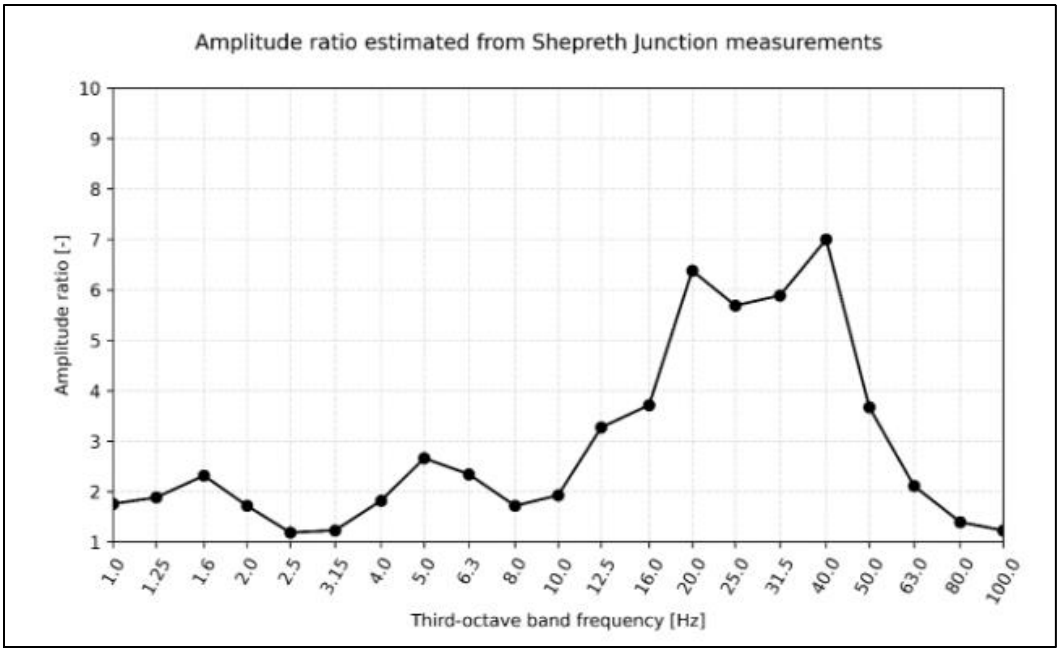

Figure 4 Amplification factor from the ES

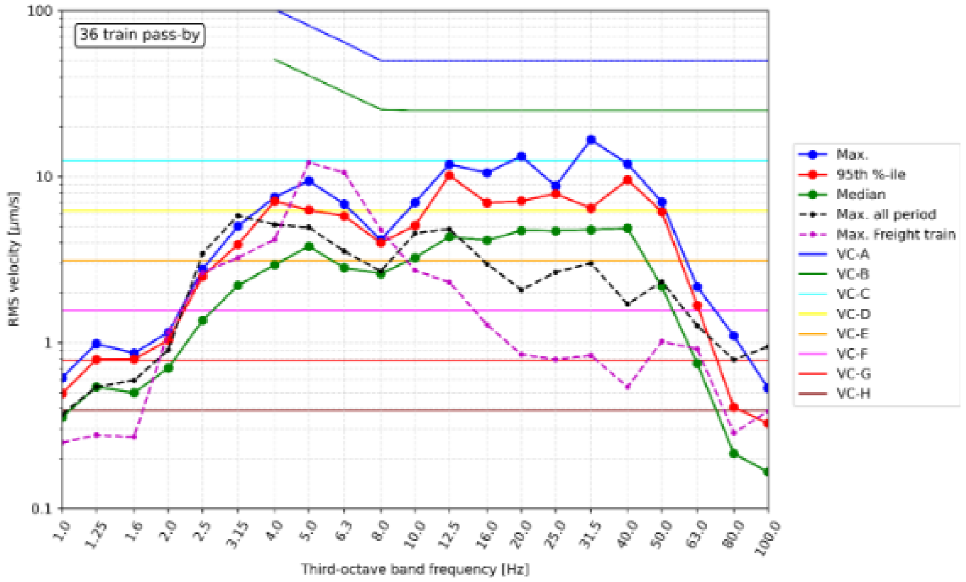

Figure 6-36: Predicted vibration levels in the vertical direction at VML1A in the north-east wing of the MRC-LMB building

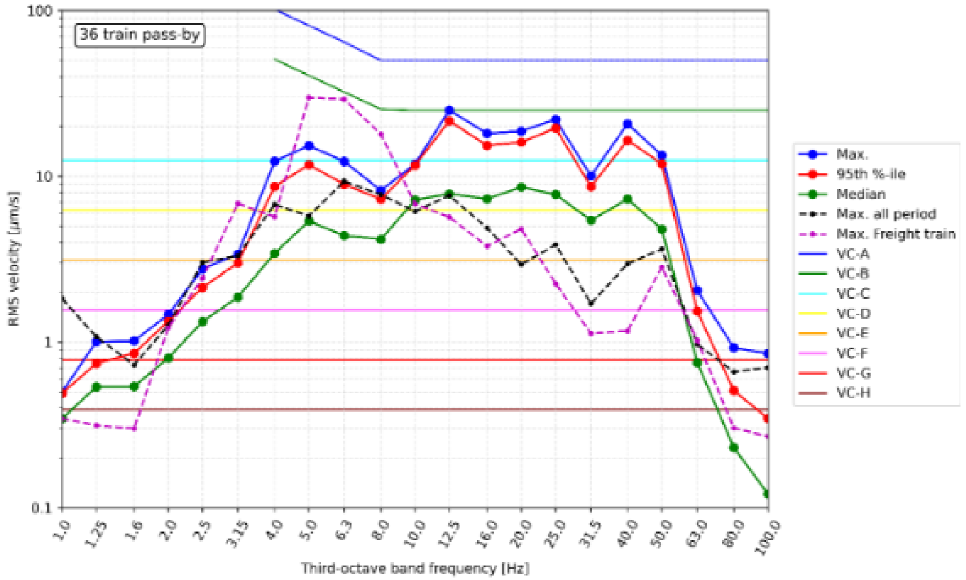

Figure 6-37: Predicted vibration levels in the vertical direction at VML1B in the south-west wing of the MRC-LMB building

Figure 5 Effect of switches and Crossing from the ES

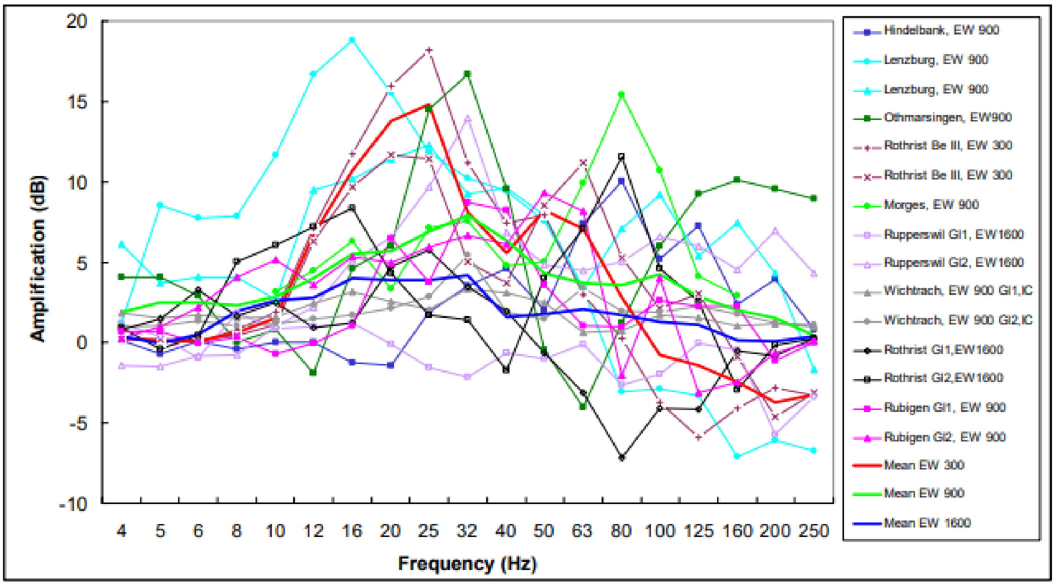

Figure 6 Extract from RIVAS 2013 (Figure 2.29a)