CROSSRAIL INFORMATION PAPER

D10 – GROUNDBORNE NOISE AND VIBRATION

This paper explains the measures that will be put in place to control the effects of groundborne noise and vibration that might otherwise arise from the construction and operation of the railway in the Crossrail tunnels.

It will be of particular relevance to those in proximity to the Crossrail running tunnels.

This is not intended to replace or alter the text of the paper itself or any commitments contained in it, and it is important that you read the paper in order to have a full understanding of the subject. If you have any queries about this paper or about how groundborne noise and vibration from the Crossrail tunnels might affect you, please contact either your regular Petition Negotiator at CLRL or the Crossrail helpdesk, who will be able to direct your query to the relevant person at CLRL. The helpdesk can be reached at:

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APPROVED
Version 4 – 03/04/08

D10 - GROUNDBORNE NOISE AND VIBRATION

NOTE: An Information Paper on groundborne noise and vibration (IP D10) was published in January 2006 (Version 1). This revised Information Paper sets out an updated version of IP D10, reflecting discussions held with the London Borough of Camden, the lead local authority on the generic issue of groundborne noise and vibration, since January 2006, and replaces earlier versions.

1. Introduction

1.1 This Information Paper explains the measures that will be put in place to control the effects of groundborne noise and vibration that might otherwise arise from the construction and operation of the railway in the Crossrail tunnels.

2. Groundborne Noise

2.1 Groundborne noise could arise from the movement of trains in Crossrail tunnels, during construction of the railway, during commissioning of the railway, or once the railway is operating passenger services.

2.2 There are no UK legislative standards or criteria that define when groundborne noise becomes significant. Crossrail has therefore drawn upon available experience in constructing new underground railways, e.g. the Jubilee Line Extension, Thameslink and High Speed 1 (Channel Tunnel Rail Link). All of these projects adopted a design criterion for groundborne noise in residential properties of 40dB $L_{AMax,S}$[1]. This criterion was therefore adopted to assess the significance of potential groundborne noise impacts in residential properties during both construction and operation of Crossrail.

2.3 In the case of buildings lawfully used as reference libraries, lecture theatres, auditoria, theatres, hospitals, places of meeting for religious worship[2], schools and similar buildings, the use of which is particularly sensitive to noise or vibration, either the same or more stringent assessment criteria were adopted. The thresholds of significance used to assess the groundborne noise impacts of Crossrail are presented in Table 1 below.

[1] One of the properties of the simple time-varying sound level that is often of interest is the maximum level that it reaches, for example during the passage of a vehicle. This gives rise to the L_{Amax} index. However, instruments set to measure the time-varying sound level can be switched to two settings, "slow" or "fast". These settings affect the way in which the sound pressure is averaged. The time constant in the averaging circuit is 1 second in the case of "slow" or 1/8 second in the case of "fast". To signify which time constant is used the letter "S" or "F" is added after L_{Amax} to give either, $L_{Amax,S}$ or $L_{Amax,F}$. The slow setting gives more repeatable results.

Table 1: Construction[1, 2] and Operational Groundborne Noise Criteria

Building	Level/Measure
Residential buildings	40dB $L_{Amax,S}$
Offices[3]	40dB $L_{Amax,S}$
Hotels[3]	40dB $L_{Amax,S}$
Theatres	25dB $L_{Amax,S}$
Large Auditoria/Concert Halls	25dB $L_{Amax,S}$
Sound recording studios	30dB $L_{Amax,S}$
Places of meeting for religious worship[4]	35dB $L_{Amax,S}$
Courts, lecture theatres	35dB $L_{Amax,S}$
Small Auditoria/halls	35dB $L_{Amax,S}$
Schools Colleges	40dB $L_{Amax,S}$
Hospitals, laboratories	40dB $L_{Amax,S}$
Libraries	40dB $L_{Amax,S}$

Notes

1. Excluding the groundborne noise from the passage of the tunnel boring machine (TBM) (refer to paragraph 2.4 in the main text below).
2. Significance with respect to the construction railway is assessed subject to paragraph 2.7.
3. Significance criteria not included in the Scope and Methodology set out in Appendix A2, Vol. 5 of the Crossrail Environmental Statement, added here for clarification.
4. Meaning a place the principal use of which is for people to come together as a congregation to worship God or do reverence to a deity.

2.4 These criteria will be adopted as the performance specification for the railway as the detailed design is developed. They do not apply to the noise of the tunnel boring machine (TBM) passage, including other tunnelling related activities, which is short-term and transitory and which was therefore qualitatively described in the Crossrail Environmental Statement[3] and assessed as likely to have no significant impact.

2.5 The potential impact for construction and operation of the railway is set out in the Environmental Statement. The assessment assumes that where necessary, the potential impact is mitigated. For the temporary railway during construction the mitigation measures available were assumed to be:

[3] The term 'Environmental Statement' refers to the Environmental Statement deposited with the Crossrail Bill in February 2005, the four Environmental Statements accompanying the Additional Provisions, the four Supplementary Environmental Statements submitted during the passage of the Bill, and their Non-Technical Summaries and errata, which together comprise the Crossrail Environmental Statement. The term 'the Main ES' refers specifically to the Environmental Statement produced (with its Non-Technical Summary) in February 2005. See http://billdocuments.crossrail.co.uk/.

- the use of smooth track (new rail without corrugations or discrete irregularities) will be installed at the start of the works with joints achieving variation in rail height of not more than 2mm;
- where appropriate the use of adequate elasticity in the track support system in order to reduce the transmission of vibration and groundborne noise from the passage of rail vehicles, for example the use of resilient rail pads in the fastening system between the rails and the sleepers.
- a speed limit on construction trains of 15km/h;
- all diesel locomotives used will be fitted with efficient exhaust silencers; and
- a maintenance programme that ensures the condition of the track does not deteriorate over time thereby causing noise in breach of the agreed threshold.

2.6 The findings of the assessment (reported in the Environmental Statement) show that adoption of these measures is likely to result in the criteria for the performance specification for residential buildings, offices, hotels, schools, colleges, hospitals, laboratories and libraries not being breached at any location during the construction of Crossrail.

2.7 The nominated undertaker will endeavour to ensure that the groundborne noise from the operation of the temporary construction railway that is experienced by any theatre, large auditorium/concert hall, studio, place of meeting for religious worship, court, lecture theatre or small auditorium/hall, does not exceed the levels to which it is already subject by the presence of London Underground, other railway and road transport operations, or the levels listed in Table 1, whichever is the higher noise level, during the periods for which the buildings are in use.

2.8 During operation after construction, the following measures were assumed to be available:

- standard trackform design to use continuously welded rail;
- the rails in tunnels will be supported on resilient track support systems, and track installation will be carried out using modern technology to achieve very much more accurately laid and smoother track than exists in traditional tube tunnels; and
- floating slab track or similar technology, including where it is predicted that standard trackform would result in the criteria in Table 1 being breached.

2.9 The nominated undertaker will be required to design the permanent track system so that the level of groundborne noise arising from it near the centre of any noise-sensitive room is predicted in all reasonably foreseeable circumstances not to exceed the levels in Table 1. The nominated undertaker will be required to install the permanent track using a standard track system for the Crossrail tunnel sections. In any location where the standard system is predicted during detailed design to cause levels of groundborne noise exceeding the relevant assessment criterion an enhanced track support system will be installed.

2.10 The nominated undertaker will put in place measures that will ensure that at no point during the operational life of the Crossrail passenger service will the combined power spectral density of the wheel and rail roughness amplitudes be worse than 30 dB re 1 micron in the 1/3 octave centred on a wavelength of 2m, decreasing by 15 dB per tenfold reduction in wavelength.

2.11 Prior to opening, the nominated undertaker will ensure that the rails of the underground sections of Crossrail are conditioned by grinding, or other suitable means, and are appropriately maintained thereafter. The nominated undertaker will be required, as part of the final track design development, to provide details to the local authorities addressing the frequency of routine maintenance regimes, and the criteria under which maintenance activities such as wheel turning and rail grinding will be triggered, to demonstrate that Best Practicable Means will be adopted in respect to those matters so far as relevant for the purpose of maintaining the system to achieve the performance levels set out in Table 1 above.

2.12 The findings of the assessment (reported in the Environmental Statement) show that adoption of these measures is likely to result in the criteria for the performance specification not being breached at any location during the operation of Crossrail.

2.13 In recognition of the local authorities' preference for groundborne noise levels within residential dwellings which are no greater than 35dB $L_{Amax,S}$ during the operation of Crossrail, the nominated undertaker will provide the information identified in paragraph 4.2 to the relevant local authority where any residential property is predicted through modelling as being likely to experience noise levels exceeding 35dB $L_{Amax,S.}$

2.14 Further as paragraph 1.5 of the Environmental Minimum Requirements explains, the nominated undertaker will use reasonable endeavours to adopt mitigation measures that will further reduce any adverse environmental impacts caused by Crossrail, insofar as these mitigation measures do not add unreasonable costs to the project or unreasonable delays to the construction programme. This requirement will be applied to any residential property in which the level of groundborne noise arising from the operation of the Crossrail passenger service near the centre of any noise-sensitive room is predicted to equal or exceed 35dB $L_{Amax,S.}$

3. Groundborne Vibration

3.1 During the detailed design stage referred to in paragraph 2.9, the nominated undertaker will also be required to design the permanent track system, in accordance with the guidance in British Standard 6472:1992 "Guide to evaluation of human exposure to vibration in buildings (1 Hz to 80 Hz)", so that operational vibration arising from it at buildings identified in Table 1, expressed as vibration dose value (VDV), is predicted in all reasonably foreseeable circumstances not to exceed the levels presented in Table 2.

3.2 The nominated undertaker will endeavour to ensure that the groundborne vibration from the operation of the construction railway that is experienced by any theatre, large auditorium/concert hall, studio, place of meeting for religious worship, court, lecture theatre or small auditorium/hall, does not exceed the levels to which it is already subject by the presence of London Underground, other railway and road transport operations, or the levels listed in Table 2, whichever is the higher vibration level, during the periods for which the buildings are in use.

Table 2: Construction and Operational Vibration Criteria

In the Absence of Appreciable Existing Levels of Vibration		**Appreciable Existing Levels of Vibration[1, 2]**
VDV $ms^{-1.75}$ Daytime (07:00 – 23:00)	VDV $ms^{-1.75}$ Night-time (23:00 – 07:00)	% Increase in VDV
0.31	0.18	40

Notes:

1. Highest impact category used, daytime or night-time.

2. There is an appreciable existing level of vibration where daytime and night-time vibration dose values (VDVs) exceed 0.22 $ms^{-1.75}$ and 0.13 $ms^{-1.75}$ respectively.

3.3 The potential impact of Crossrail trains running through tunnels during construction and operation of the railway has been assessed and the findings reported in the Environmental Statement. The running of both the construction and permanent railways is not forecast to cause vibration impacts which will be felt by those occupying the buildings above.

3.4 Vibration from the passage of the tunnel boring machines may be perceptible. However, this will be a transient effect lasting only a few days at any one location and will not cause damage to buildings.

4. Application of the Crossrail Design Criteria to the Design of the Permanent Track System

4.1 The nominated undertaker will be required to do the following in relation to the permanent track system[4] for the tunnel sections:

a) At design stage, to apply the relevant Crossrail design criteria relating to Tables 1 and 2 which are referred to above to predict, through the use of appropriate modelling[5], the engineering requirements of the track system to meet those criteria.

[4] The track system will comprise the integration of those component parts that together provide the guidance and support to the rail vehicles, including the rails, fastenings, resilient elements and any sleeper, ties, block or slab that transfers the track loads into any tunnel or structure base slab and which together determine the track stiffness and rail restraint.

[5] For typical residential buildings appropriate modelling is likely to be the generation of contours such as those used for the Environmental Assessment. Buildings with deep foundations will be subjected to more detailed calculation; In both these cases the modelling will follow the guidance of 8.2.2.3 and 9.2.2 of BS ISO 14837:2005. Buildings with more demanding criteria or having complex foundations or structures will be subjected to full numerical modelling following the guidance of 8.2.2.4 and 9.2.3 of BS ISO 14837-2005.

b) In acting under paragraph (a) above, to design a standard trackform[6] for the tunnel section with the objective of meeting as many of those design criteria as can reasonably be achieved by such a standard track system and to design an enhanced trackform, such as floating slab or alternative better technology, for locations where it is predicted that the standard track system will not meet the criteria or to discharge other project commitments and undertakings.

c) To translate the engineering requirements established under paragraphs (a) and (b) above into contract specifications[7] for the permanent track system.

d) To procure and install a permanent track system to meet the contract specifications established at (c) above.

4.2 The nominated undertaker will be required to provide details of the steps taken and to be taken in accordance with paragraph 4.1 above to the relevant local authority, whose comments will be taken into account, including modelling results and details of the type of rail/and or track support system proposed and its predicted performance, and to continue technical discussions concerning groundborne noise issues with local authorities. In accordance with paragraph 2.13, this will include any situation where groundborne noise levels are predicted to exceed 35dB $L_{AMax,s}$ but be less than 40 dB $L_{AMax,s}$ in residential properties.

5. Predictive Modelling of Groundborne Noise

5.1 For the detailed design of the permanent track system in Crossrail tunnels, the nominated undertaker will be required to adopt a groundborne noise and vibration prediction model that is fully compliant with the guidance provided in ISO 1487-1:2005 “Mechanical Vibration – Groundborne noise and vibration arising from rail systems – Part 1: General Guidance”, and will provide details of the model development, calibration, validation and verification procedures undertaken to comply with that guidance and the resulting model accuracy to the local authorities whose comments will be taken in to account.

[6] The standard trackform for this purpose does not include an enhanced trackform such as floating slab or alternative equivalent or better technology.

[7] The contract specifications will set requirements for the manufacture, installation and maintenance of the track system as a guidance system with ancillary functions for other system demands. The measurement of consequential noise and vibration levels at buildings or other receptors will not be included as a contract specification.