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Transport Infrastructure Ireland

Prediction of Groundborne Noise From Groundborne Vibration

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PREDICTION OF GROUNDBORNE NOISE FROM GROUNDBORNE VIBRATION

The Board has asked how the operational groundborne noise levels within building spaces overlying the Metrolink alignment have been established from the predicted FINDWAVE® free-field vibration magnitudes at the ground surface.

The prediction of vibration (and its secondary effect, groundborne noise) from railway tunnels involves modelling firstly the source of vibration such as the rolling of rail wheels on rails, secondly the vibration transmission characteristics of the track support system, thirdly the dynamic behaviour of the tunnel structure, fourthly the propagation characteristics of the lithology surrounding the tunnel up to the ground surface, and fifthly the response of buildings above.

This note addresses the fifth matter – namely the relationship between ground vibration and vibration/groundborne noise inside the building. This is clearly to some extent dependent on the structure of the building and the dimensions of its rooms which vary across building types, but in order to facilitate predictions over a large area along the alignment of a proposed railway tunnel it is appropriate to derive a typical relationship between external vibration and internal vibration/groundborne noise. For this reason the topic has been considered in a number of standards and guidance documents. The quantities to be determined are (a) the coupling loss factor, which is the reduction in vibration that occurs in transmission from the soil to the building foundations, and (b) the effect of any amplification that arises due to resonant modes in floor structures in the building. In general, (a) decreases vibration and (b) increases it. Finally, having predicted internal vibration it is necessary further to predict the level of sound that will result in rooms, that is, sound which has been radiated by a vibrating surface such as the floor.

A number of organizations have carried out field measurements to determine the magnitudes of coupling loss factor and floor amplification. The most widely cited publication of these results was the US Department of Transportation Report by authors Nelson and Saurenman. This showed that at the frequencies which predominate in the spectrum of vibration above a modern underground railway, the coupling loss factor and the amplification of a suspended floor are such that they approximately cancel out. This means that ground surface vibration may be taken as a proxy for floor vibration inside a typical residential building. This is further confirmed in the 2009 US publication by the Transit Cooperative Research Program (TCRP) [1] who found that "*Although there is considerable spread in the data (up to ±10 decibels), the best-fit line is very nearly given by, $L_{v(Indoors)} = L_{v(Outdoors)}$*" where L_v is the level of vibration expressed using the decibel scale. There remains the conversion from L_v to sound pressure level in the rooms concerned known as L_p, and in terms of A-weighted decibels, the document reports that $L_{pA}=L_{vA}-32$ dBA (expressed using the European reference for the L_v scale, 1×10^{-9} m/s, rather than the US reference of 1 microinch/second). However, for most assessment of new underground railways in the UK and Ireland it is cautiously assumed that $L_{pA} = L_{vA}-27$ dBA. This topic is also addressed in Annex A of ISO 14837-31[2], where a similar simplified method is presented in Annex A.3.3 as $L_{p,av} \approx L_{v,meas,floor} - 27$ dB (when velocity levels are referenced to 1×10^{-9} m/s). In the publication Railway Noise and Vibration[3] the same approach is described as "*an established, appropriate general equation for estimating the sound pressure level from the vibration level prediction. It can be used in the prediction scheme for most buildings without a need for specific information about the interior of the building or other information that is too detailed.*" Finally, the Association of Noise Consultants (ANC) publication Measurement and Assessment of Groundborne Noise and Vibration[4] refers to measurements undertaken near to the London Underground Central Line which showed

[1] Ground-Borne Noise and Vibration in Buildings Caused by Rail Transit. Transit Cooperative Research Program. TCRP Report for Project D-12, Document 48

[2] International Standard Organisation ISO 14837 Mechanical vibration — Ground-borne noise and vibration arising from rail systems — Part 31: Guideline on field measurements for the evaluation of human exposure in buildings. 2017

[3] Railway Noise and Vibration. Mechanics, Modelling and Means of Control. David Thompson. 2009

[4] Association of Noise Consultants. ANC Guidelines. Measurement and Assessment of Groundborne Noise and Vibration. 3rd Edition 2020.

that using the external free-field vertical vibration instead of the floor vibration in the equation $L_p = L_v - 27$ dB was more successful in predicting groundborne noise in buildings. This supports the assumption described above that the coupling loss is cancelled out by the floor amplification. The buildings surveyed in this London Underground study were domestic brick built houses with sprung timber floors similar to those along the route of the Metrolink.

For specific buildings with special sensitivities to vibration from Metrolink, numerical modelling using the finite-difference-time-domain package Findwave has been used, and these models include the building in as much structural detail as is available so that the coupling loss and floor amplification effects are included in the modelling process. For the large number of residential properties along the alignment it has not been practical to carry out detailed modelling of the buildings, and the system-wide assumption that $L_{pA}=L_{vA}-27$ dBA has been applied in the generation of the contours and the tables in the EIAR. These predictions take account of all five effects described in the first paragraph above.