A summary of comments for Oxford City Council on a 'Technical Note' of 17 December, prepared by Atkins Ltd for Network Rail, and forwarded to the Council in support of the Vibration Scheme of Assessment for East-West Rail Phase 1

By Paul Buckley, 10 February, 2015.

The Vibration Scheme of Assessment (VSoA) was submitted by ERM on behalf of Chiltern Railways and Network Rail in support of their application for discharge of Condition 19 of the TWA Order relating to East-West Rail Phase 1 (EWR1). The Arup review commissioned by Oxford City Council independently highlighted two serious weaknesses of the VSoA.

1. Its neglect of the possibility of building resonances amplifying vibration amplitudes.
2. Its unconvincing treatment of inter-train variability in the measurements used as the basis of the vibration predictions.

The Technical Note is a response to these observations.

## Allowance for building resonances

It is well known that the amplitudes of ground-borne vibrations are modified when they enter and are transmitted through buildings. There is a complex chain of attenuation (from soil-to-building transmission and the damping properties of building materials) and amplification (from structural resonances), that differs from building to building, and varies within buildings. Therefore the assumption made in the VSoA, that the worst vibration to be suffered within every building near the Oxford-Bicester railway line will be identical to that in adjacent open ground, is so crude that it rules out any chance of reliable predictions based on it. This is a major reason why the VSoA's vibration predictions are so unsafe.

Given that the vibration response is complex and differs so much between buildings, the practical problem in predicting the impact of a scheme such as the EWR on a whole community, is how to make predictions that are **reasonable** but also **unambiguously cautious** for multiple buildings, while avoiding the need to model or

measure the response of each individual building. Arup, in their report, recommend an approach that has been used with success in the UK for numerous major projects – most recently, in preparing the Environmental Statement for all 26 sections of the HS2 project. It is based on a large amount of empirical data obtained in the UK in the 1990s, supplemented by similar data from continental Europe, well explained in the relevant Technical Appendix of the HS2 Environmental Statement[1]. The approach used is to multiply ground vibrations, expressed in VDV, by a net amplification factor of 2 for ground floors and of 4 for 1st floors in buildings (the 1st floor is considered most vulnerable). In the case of Wolvercote, where several buildings of two or more storeys, of different design, are close to the line and potentially vulnerable to high levels of vibration from trains, the Arup recommendation of applying a net amplification factor of 4 seems to me a soundly-based and pragmatic approach.

The recent Technical Note adopts a different approach. It says a building surveyor visited Wolvercote on 11 December 2014 *'to identify the basic structural features'* of three of the buildings most vulnerable: Quadrangle House, 2B and 3 Bladon Close. On the basis of this *'visual inspection'*, a value for the net amplification factor for each building was determined using data given in the ANC guide 'Measurements and Assessment of Groundborne Noise and Vibration' (the relevant data are from the USA and from the UK prior to 1987). The *'reasonable worst case'* factors suggested by the Technical Note vary widely: from 0.63 to 5.01[2]. They are applied to some *'open ground'* VDV values, to obtain VDV predictions for inside these three properties. The resulting figures all lie below the NVMP thresholds, leading to the Technical Note's conclusion that *'VSoA results in robust conclusions with a reasonable margin of safety'*.

However, this conclusion is unsound. The Technical Note's approach can be criticised for speculating on how these three buildings will respond to ground-borne vibration, on the basis of only a superficial inspection. But the major error it contains is more

[1] HS2 London - West Midlands Environmental Statement, Volume 5: Appendix SV-001-000: Annex D1.
[2] Net amplification factors referred to here are obtained from the 'Net Effect dB' values given in the table on p.5 of the Technical Note.

fundamental. In its calculations reported in the Table on p.6, the Technical Note uses values for the 'open ground' VDVs, which appear to be unreasonably low. There are three apparent errors in the Table. (1) The 'open ground' VDVs given for 2B and 3 Bladon Close are much lower than those predicted in the VSoA for 3 Bladon Close after implementation of EWR. It is unclear where they come from. (2) No allowance has been made for amplification from the crossings associated with the set of points next to Bladon Close. (3) 4 Bladon Close should have been included but wasn't (it is the building nearest the crossings and hence one of the most vulnerable buildings in Wolvercote).

The following table summarises what I believe to be the best estimate of the *correct* position. It compares the effects of applying the amplification factors suggested by (a) the Technical Note ('worst case' values), or (b) Arup. The 'open ground' VDVs in rows 1-3 are as calculated by myself, using only data given in the two parts of the VSoA (Plain Line and Switches and Crossings) and following the calculation method of Approach 1 of the VSoA. Where my 'open ground' values can be compared with the VSoA (4 Bladon Close, including the effects of the crossings), they agree quite closely as expected – as was true for all the other receptors mentioned in the VSoA[3]. This validates the 'open ground' values. I have included the significant effects of the crossings for 3 Bladon Close too (ignored for this building in the VSoA). I have assumed that 2B Bladon Close has the same open ground VDV as 3 Bladon Close but without the effects of the crossings (since it is considerably further away from them). I have assumed that 4 Bladon Close has the same construction as 3 Bladon Close (and therefore the same worst case net amplification factor according to the Technical Note).

[3] See "East West Rail: vibration scenarios including switches and crossings", C.P.Buckley, 7 October, 2014. As pointed out there, agreement with the VSoA is sometimes not perfect, because of rounding error. I rely on input data from the VSoA, but in many cases this had been rounded to a very small number of significant figures.

| | Open ground VDV | | With factor from Technical Note | | | With factor from Arup | | |
|---|---|---|---|---|---|---|---|---|
| | day | night | factor | day | night | factor | day | night |
| Quadrangle | .145 | .092 | .794 | .115 | .073 | 4 | .580 | .370 |
| 4 Bladon Close | .177 | .096 | 3.16 | .559 | .303 | 4 | .708 | .383 |
| 3 Bladon Close | .185 | .104 | 3.16 | .585 | .327 | 4 | .741 | .414 |
| 2B Bladon Close | .112 | .061 | 5.01 | .561 | .307 | 4 | .448 | .245 |

| Key to compliance with Condition 19: | .*** | Compliance | .*** | Non-compliance |
|---|---|---|---|---|

The table shows that, provided correct 'open ground' VDV predictions are used in the calculation, there are some buildings where the NVMP vibration thresholds will be exceeded (by large margins), *irrespective of whether the Technical Note's amplification factors are used, or Arup's*. The only really significant difference is that, if the Technical Note's factors are used instead of Arup's, Quadrangle is predicted to escape vibration above the threshold values.

## Inter-train variability in the VSoA vibration survey measurements

All the open ground vibration predictions in the VSoA are based on baseline values, derived from measurements made during the vibration survey. A very important question determining the validity of the predictions, is how well the statistical distribution of data collected matches that of the population of trains that will run in future on the Oxford-Bicester line.

The Arup report (p.6) points out that, in Arup experience, freight train vibrations are usually more variable than indicated in the VSoA measurements. This suggests that

the data recorded by Atkins were not objectively representative of the trains running on the DCL line (where most of the measurements were made). The Technical Note counters this observation as follows (p.6/7): *"Measurements undertaken as part of the VSoA have monitored all available trains past the measurement point over 3 different days. The sample size is a reflection of the current use of the line"* (i.e. the DCL line). But this is inconsistent with the VSoA, where it appears that only *ca* 14% of the trains running on those days were recorded – see "Failures of the Atkins Report" by Keith Dancey and myself, Appendix 2. At the public Technical Meeting held in Wolvercote on 10 June 2014, residents questioned the Atkins representative on what steps were taken to ensure that an objective selection of trains was monitored, but without success. He stated only that trains were monitored that happened to pass by during the hours when Atkins personnel were present. He could not recall what hours those were. He did not explain how they were chosen. Thus doubt remains about whether the Atkins data set, especially for freight trains, is representative. Consequently, the Atkins 'open ground' VDV values may be based on unreliable baseline data, and hence could be under-predictions[4]. Arup suggested that a pragmatic means of correcting for this doubt would be to multiply 'night' VDV predictions by a further factor of 1.4 (corresponding to the passage of one stone train during the night hours). The effect on the table above would clearly be to make the margin by which the night-time VDV exceeds the threshold at some buildings even greater.

## Summary

- The Technical Note is dangerously misleading in a number of respects.
- It claims that using building response amplification factors from the ANC guide instead of the Arup factor of 4 leads to all predicted VDVs in Wolvercote being below the NVMP vibration thresholds. But this is not the case. Using correct values for open ground VDVs, several buildings, at least,

[4] The Technical Note refers misleadingly to the presence of a 'reasonable margin of safety' that might be thought to compensate for unrepresentative input data. But in reality, such a margin of safety, if any, is small and ill-defined. The use of baseline VDVs above the mean, as used in the VSoA, is required to compensate statistically for the finite size of the data set, and for the special mathematical properties of the 4th power averaging in the definition of VDVs: it does not constitute a 'safety margin' in the usual meaning of the term.

are predicted to suffer levels of vibration above the thresholds, irrespective of which set of amplification factors is used.

- It claims that the vibration data used to determine baseline values for the predictions of VDV were fully representative of trains running on the DCL line because 'all available' trains were monitored. But this inconsistent with the VSoA and information provided by Atkins at the Technical Meeting. Only a small proportion of trains was monitored on the days concerned: how these were selected has never been divulged.
- The clear conclusion is that there is a real danger that NVMP vibration thresholds will be exceeded in Wolvercote as a result of the EWR1,2A,2B scheme. In spite of this, no mitigation has been proposed as required by the NVMP[5]. Therefore the scheme remains non-compliant with Condition 19 of the TWAO. The recent Technical Note does not change this.

[5] The NVMP says: *"Trackforms will be designed and installed adjacent to occupied vibration sensitive receptor buildings using Best Practicable Means to keep within the thresholds"*.