Lower Thames Crossing

6.3 Environmental Statement Appendices
Appendix 12.9 - Effects of Vibration from Road Traffic (Highways England Ref. 1-457 Noise Support 2017-2021)

APFP Regulation 5(2)(a)

Infrastructure Planning (Applications: Prescribed Forms and Procedure) Regulations 2009

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Executive Summary

Possible impacts from road traffic induced vibration are often scoped out from scheme assessments, following the approach which is suggested within HD213/11. This task is to determine whether the assumption of no impacts from operational vibration is valid, and to provide assurance that it can be scoped out from assessments.

This task relates to groundborne vibration from road traffic, and airborne vibration is therefore not discussed. A review of published literature regarding groundborne vibration from road traffic is presented, with the aim of determining whether operational vibration is an area which can be scoped out of assessment. The review also considers the magnitude of vibration which is considered acceptable for a scheme, and at what magnitude vibration impacts should be scoped in.

This task considers 'normal conditions' and the potential for disturbance from groundborne vibration above tunnels. Vibration measurements have been undertaken both adjacent to the carriageway and above two types of tunnel. It is considered that the measurement results provide sufficient evidence to scope out the assessment of groundborne vibration for receptors; located above road traffic tunnels and located adjacent to the carriageway.

The results can be used to inform ongoing and future assessments and the re-draft of HD213/11.

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TABLES

FIGURES

1. Current Position

HD213/11 mentions groundborne vibration in several places through the document. A summary of the key points is that operational groundborne vibration is a low frequency disturbance that can produce physical movement in buildings and annoyance to their occupants. It is produced by the interaction between rolling wheels and the road surface, and is often in the 8-20 Hz frequency range. Groundborne vibration is usually expressed in terms of Peak Particle Velocity (PPV), which is often measured in mm/s (i.e. the maximum speed of movement of a point during the passage of a source of vibration). For vibration from traffic, a PPV of 0.3 mm/s measured on a floor in the vertical direction is perceptible, and structural damage to buildings can occur when PPV levels are above 10 mm/s. PPVs in the structure of buildings close to heavily trafficked roads rarely exceeds 2 mm/s and are typically are below 1 mm/s. If the level of vibration at a receptor is predicted to rise to above a level of 0.3 mm/s, or an existing level above 0.3 mm/s is predicted to increase, then this should be classed as an adverse impact from vibration.

It is common practice for design agents to scope out groundborne vibration impacts from assessments on the basis that the usual resurfacing that is part of a scheme would result in a smoother running surface, and would reduce any existing vibration impacts. An example taken from the A14 Cambridge to Huntingdon Improvement Environmental Statement is given below, and is typical of the approach taken by the majority of design agents in the assessment of vibration from road traffic;

“Operational vibration: no calculations have been necessary. As set out in DMRB HD213/11 (Highways Agency et al., 2011), appreciable groundborne vibration is not generated by a road with a well-maintained road surface and the potential for airborne vibration (e/g/ from HGV exhausts) is factored in to the assessment of airborne noise.”

2. Literature Review

Normal Conditions

Normal conditions are considered to be an existing road with free-flow conditions. It is assumed that the surface is smooth and continuous, and wherever there are irregularities in the road surface then these would be resolved by routine maintenance. In the context of the assessment of a road scheme it is anticipated that resurfacing would occur, and that the resurfacing would result in a smooth and continuous surface. Normal conditions would also reflect the situation where the source and receptors are at a similar elevation, with no large changes in ground level as a result of earthworks. Normal conditions also relate to residential receptors, where there are receptors that may more sensitive to vibrations (e.g. laboratories) then these should be considered on a case by case basis.

Situations that would be considered to be outside of normal conditions may include a road elevated on a structure, the introduction of traffic calming or a situation where there are extensive earthworks resulting in large change in elevation of the road relative to nearby receptors.

Magnitude of Vibration

HD213/11 suggests a threshold vibration PPV of 0.3 mm/s as a level below which vibration from road traffic is unlikely to be perceptible. Where there is existing vibration above 0.3 mm/s, or where vibration is expected to increase to above this level then there would be an adverse impact. HD213/11 also states that where vibration levels are above 10 mm/s then structural damage to buildings can occur.

The level of 0.3 mm/s corresponds to information presented in BS 5228-2, stating that PPV of 0.3 mm/s may just be perceptible in residential environments. The quoted level of 10 mm/s for possible structural damage is more conservative than the guidance presented within BS 7385-2 indicating 15 mm/s PPV or higher for transient cosmetic damage to residential buildings in the frequency range 4Hz to 15Hz. The standard also notes that the probability of damage tends to zero at a PPV of 12.5 mm/s.

It is considered that a PPV of 0.3 mm/s is the appropriate threshold for determining when vibration may be perceptible in a residential environment.

Watts, G.R. (1990). Traffic induced vibrations in buildings. TRRL RR246, Transport and Road Research Laboratory, Crowthorne. (RR246)

This document is one of the key references for HD213/11 in relation to groundborne vibration. The document describes the nature of traffic induced vibration, and methods for predicting the degree of disturbance that is likely from both airborne and groundborne vibrations. It concludes that although traffic vibration can cause severe nuisance to occupants there is no evidence to support the idea that traffic vibration can cause significant vibration to buildings.

Page 6 states “Perceptible groundborne vibrations would be expected in dwellings situated a few metres from roads with uneven road surfaces and carrying HGVs.”

Page 8 states “measurements of vibration near the house foundations revealed that groundborne vibrations were only likely to be perceptible at a relatively small number of houses which were close to significant surface irregularities.”

Hunaidi, O. and Tremblay, M. Traffic induced building vibrations in Montréal. Canadian Journal of Civil Engineering, Vol. 24, No. 5, 1997, pp. 736–753. (Hunaidi and Tremblay)

The study undertook measurements and analysis of building vibrations induced by road traffic in Montreal at nine sites at various distances up to 14m from the road. Vibration levels were evaluated with reference to human annoyance and also the potential for building damage using existing International standards, including some from the UK. The effects of road condition and seasonal variations in soil conditions on vibration levels were also investigated, before and after a road was resurfaced and in different seasons. At most locations the tests were undertaken to evaluate the transmission of vibrations from a discrete irregularity in the road surface to nearby buildings, simulated by fixing a wood plank to the carriageway adjacent to the receptor building.

Measurements of PPV taken in the basements of the buildings and near to walled foundations were in the range 0.25 mm/s PPV to 2.23 mm/s PPV. Of the seven values presented, six were above the 0.3 mm/s level of perception in residential environments, and all seven were below the 15 mm/s level for cosmetic damage to buildings.

The study states that traffic vibration is mainly caused by heavy vehicles, and rarely by small vehicles (cars), if at all. It also states that vibrations are induced as a result of the presence of irregularities in the road surface, for instance potholes, cracks etc. The study used a typical transit bus and city truck on the roads for the purposes of vibration measurements.

Controlled tests were carried out at one of the sites to evaluate the effect of road resurfacing, and also seasonal variations in soil conditions. It was found that the resurfacing of a road results in a reduction of vibration levels. Overall the potential of traffic vibration resulting in building damage was considered very small for the conditions in Montreal.

JACOBS, (April 2016), M6 Junctions 16 to 19 Smart Motorway Baseline Vibration Monitoring Report (Jacobs 2016)

A resident living near to the M6, between Junctions 16 and 17, expressed concerns that the M6 Junctions 16 to 19 Smart Motorway scheme could lead to a worsening in vibration levels at his property arising from road traffic using the scheme. The scheme will utilise the current hard shoulder as a permanent running lane and, therefore, road traffic will be running slightly closer to the property on a permanent basis. It was decided by the Project Manager to undertake a series of vibration measurements.

Baseline vibration monitoring was carried out prior to the start of construction works to capture the vibration environment at the property. Measurements were undertaken over a two-week period in early 2016 at two locations. The property is located at approximately 30m from the closest running lane of the M6 northbound carriageway. Measurements were undertaken at a location in the garden area and also in an unoccupied upstairs bedroom within the house.

Measurements of VDV both in the garden area and also inside the house indicated generally low levels of vibration, below the level at which there is a low probability of adverse comment (BS 6472-1). Although there were measured levels above 0.3 mm/s PPV at both locations, the high vibration events did not correlate with each other, suggesting that the vibration events noted inside the property occurred independently to the vibration events noted outside the property. It is therefore considered that the high vibration events were not due to the road, as a degree of correlation would be expected if this were the case.

There is no conclusion drawn within the report, but this survey would suggest that at a distance of 30m from the motorway there is no risk of damage from vibration and it is unlikely to be at a level which is perceptible.

Tunnels

A search of known assessment reports associated with schemes that include a road tunnel has been carried out.

The now completed tunnel at Hindhead on the A3 passes under a group of residential dwellings. At this location road traffic induced vibration was not identified as a potential impact in the Environmental Statement, or at Public Inquiry. The acoustic consultants who undertook the assessment (Atkins) are not aware of any complaints from the operation of the tunnel.

The M25 Junctions 23 to 27 Managed Motorways scheme was completed in 2014, which passes under an existing cut and cover tunnel just east of Junction 25 at Waltham Cross. Groundborne vibration from road traffic was not identified as a potential impact in the Environmental Statement. There were also no consultation responses identifying vibration from road traffic as an area of concern.

In addition, there are no known vibration complaints from locations above road tunnels.

Literature Review Recommendations

Normal conditions

There is a consensus that where a road is smooth and continuous that traffic induced groundborne vibrations are not likely to cause damage to buildings. This is stated in both RR246 and also Hunaidi and Tremblay.

The measurement results and conclusions presented by the Hunaidi and Tremblay support the approach that where a road scheme includes resurfacing that there is a reduction in traffic induced groundborne vibration.

The Hunaidi and Tremblay study, together with the vibration measurement results presented in the 2016 Jacobs report, provide reassurance that under normal conditions groundborne vibration is unlikely to result in cosmetic damage to residential buildings.

It is considered that between these three reports there is sufficient evidence to support the approach outlined in HD213/11, and scope out the need for groundborne vibration assessment of existing roads under normal conditions. Where a scheme involves variation from normal conditions then the author should consider groundborne vibration in each case.

Tunnels

As we have not uncovered examples of adverse impact, or complaints, from vibrations from road traffic above tunnels it is considered that this potential impact could be scoped out from assessments. In order to provide evidence for this approach, vibration surveys have been undertaken, as outlined in the next section.

3. Vibration Surveys

Locations and Equipment

The vibration measurement equipment used at both locations was a Vibra Profound (serial number VIB01731). Vibration was recorded as PPV in the longitudinal (y-axis), transverse (x-axis) and vertical (z-axis) orthogonal planes. Triaxial measurements of the three perpendicular axes measured simultaneously were undertaken. The Vibra Profound meter was set to record the maximum PPV at 1-second intervals for the measurement period.

Measurements of vibration have been undertaken at three locations. The first location was a cut and cover tunnel over the A1(M) at Hatfield. The second location was the A20 in Kent, over a bored tunnel. The third location was adjacent to a service building adjacent to the A20. The first and second locations are considered to be representative of other similar tunnel locations on the Highways England road network.

Cut and cover tunnel, A1(M) Hatfield

This location is an example of a cut and cover tunnel over the busy A1(M). Figure 1 indicates the location of the survey, which was at the end of Walsingham Close (UTM 51°45'55'' N 0°14'10'' W).

Figure 1 – Hatfield Tunnel Vibration Survey Location

The vibration transducer was placed directly on the hard surface car park, at a location above the south-bound carriageway of the A1(M) Hatfield Tunnel. The location was approximately 40 m from the nearby A1001 Comet Road. As this location is a cul-de-sac there was no regular pass-by of local vehicles.

A note was made of any nearby activities that could result in a vibration event. At 10:09:25 a large tractor passed by on the A1001 Coment Way, resulting in a tri-axial vibration peak of 0.197 mm/s PPV. A van also passed within 10 m of the equipment undertaking a u-turn in the Walsingham Close car park at 10:26, although no particular vibration peak was noted for this event.

Bored Tunnel, A20 near Folkestone

This location is a bored tunnel, with the A20 passing through, Figure 2 indicates the survey location. The measurement at this location was of a 30-minute duration. The accelerometer was located at the north-east tunnel portal on top of the tunnel up on the bank at approx. 18 m from the tunnel portal (UTM 51°06'08.6'' N 1°10'13'' W).

Figure 2 – A20 On top of bored tunnel - Vibration Survey Locations

The vibration transducer was mounted to the Profound ground spike and pushed into the ground. The ground at the location was firm and considered to provide a solid transmission path to the tunnel structure.

During the duration of the survey there was an observed constant road traffic flow on the A20 with consistent flow of Heavy Goods Vehicles (HGV) entering the tunnel. During the measurement there were no noted vibration events.

The road surface at the section just before the tunnel portal and inside the tunnel on A20 was thought to be HRA. The road surface was not new or totally smooth, and some small areas of roughness and discontinuities were noted. Figure 3 shows a section of the A20 road on the approach to the tunnel portal, with arrows pointing to the areas of surface roughness.

Figure 3 – A20 Road surface near vibration survey locations

A20 Service Building adjacent to Carriageway

The survey location is at the base of the nearby service building, approx. 10m from the A20 south bound carriage way (UTM 51°5’60’’ N 1°10’13’’ W). The vibration transducer was placed at approximately 20 cm from the building foundations and directly on the hard surface of the limited access lane to the service building. No vehicles used the access lane during the survey. Figure 4 shows the survey location.

Figure 4 – A20 Service building adjacent to carriageway - Vibration Survey Location

The road surface at that section of A20 is the same as the shown in the site photos in Figure 3 where the pavement is not entirely smooth. The traffic on A20 was constant during the measurement, with a steady component of HGVs and free flowing.

Vibration Survey Results

This section provides a summary of the measured vibration monitoring data for all monitoring locations. The results are summarised in Table 1, and also presented as graphs. The graphs in Figures 5, 6 and 7 indicate the measured PPV in the X, Y and Z axis at all three measurement locations.

Table 1 – Summary of Measured PPV, mm/s

Location	Date & Time		Plane of Vibration			
			Transverse (x-axis)	Longitudinal (y-axis)	Vertical (z-axis)	Tri-axial
Hatfield Tunnel	18/05/18 09:55-10:55	Maximum PPV, All Data	0.051	0.194	0.137	0.197
		Maximum PPV, Excluding Tractor Event	0.051	0.013	0.137	0.141
		No. of occurrences >0.3	0	0	0	0
A20 Tunnel	25/05/18 12:18-12:48	Maximum PPV, All Data	0.087	0.055	0.051	0.088
		No. of occurrences >0.3	0	0	0	0
A20 Carriageway	25/05/18 13:02-14:00	Maximum PPV, All Data	0.041	0.047	0.069	0.071
		No. of occurrences >0.3	0	0	0	0

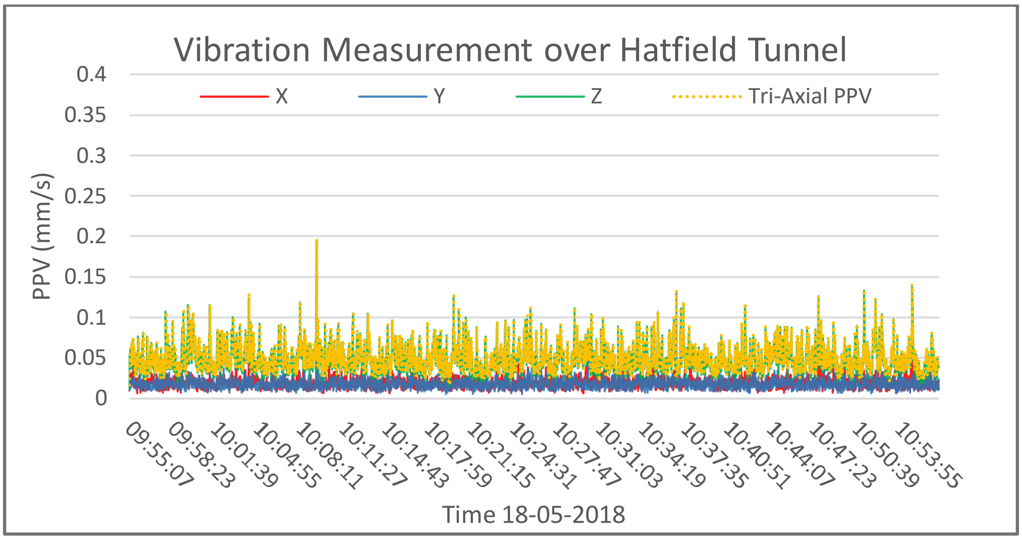

Figure 5 – Time History of Measured Vibration Levels over Hatfield Tunnel

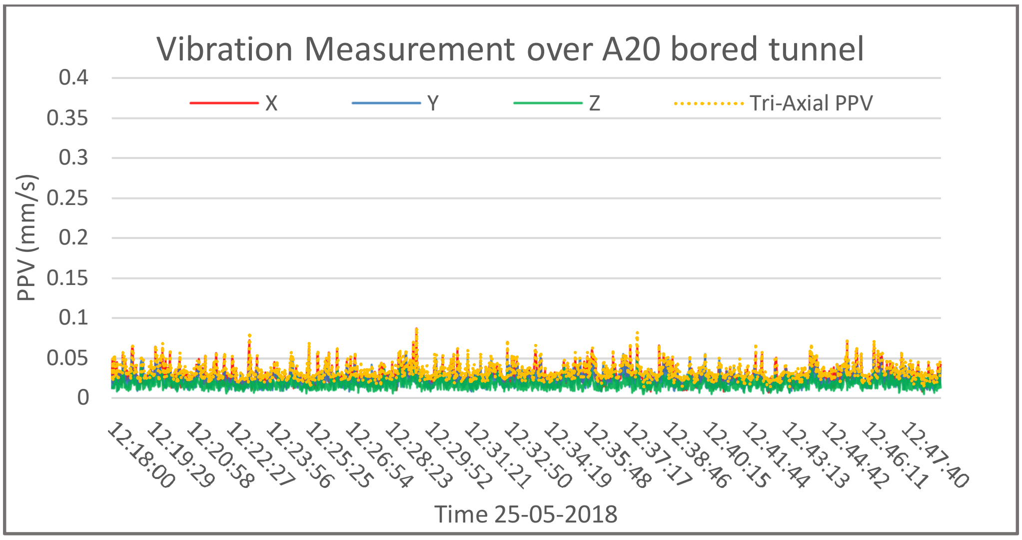

Figure 6 – Time History of Measured Vibration Levels over A20 Tunnel

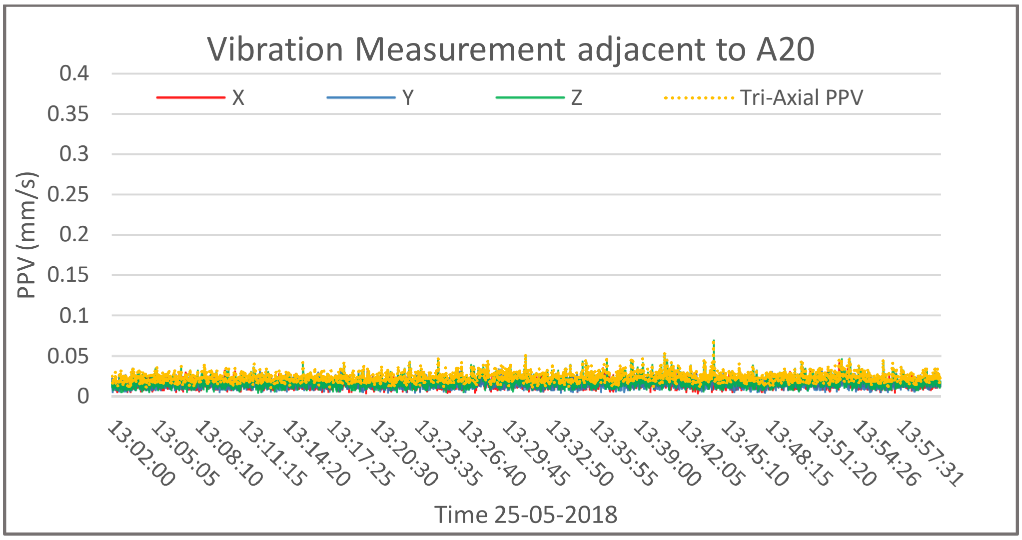

Figure 7 – Time History of Measured Vibration Levels Adjacent to A20

Measured levels of vibration over the Hatfield Tunnel are generally low, and below 0.15 mm/s. There were no exceedances of 0.3 mm/s threshold level from HD213/11, below which vibration is not considered to be perceptible.

Table 1 indicates that the maximum recorded PPV over Hatfield Tunnel was 0.197 mm/s at 10:09:25 which corresponds to the pass by of a large tractor on the A1001 Comet Way. Excluding this peak event, measurements of PPV ranges between 0.019 – 0.141 mm/s PPV during the 1-hour measurement, remaining below the threshold level of 0.3 mm/s for adverse impacts from road traffic vibration.

The PPV vibration levels measured above the A20 bored tunnel are also generally low. It can be seen that the measured PPV ranged between 0.013 and 0.088 mm/s and was generally below 0.05 mm/s. There were no exceedances of 0.3 mm/s threshold level from HD213/11, below which vibration is not considered to be perceptible.

The measurements near the building foundations adjacent to the A20 were generally below 0.05 mm/s, and remained well below the 0.3 mm/s threshold level set out in HD213/11 below which vibration is considered to not be perceptible. Only one vibration event was noted at 13:44:19 when one of the members of the staff working at the building walked near the meter, resulting in very small increase in the PPV. This was the maximum measured tri-axial level of 0.071 mm/s. No other particular vibration events were noted over the 1-hour measurement period.

Summary

Measurements of vibration from road traffic have been undertaken at two locations over tunnels and one location adjacent to the carriageway. The locations are considered representative of other similar locations on the network.

There were no recorded exceedances of the 0.3 mm/s threshold level set out in HD213/11 below which vibration is considered not to be perceptible. As the measurement results are considered typical of groundborne vibration from road traffic within other similar tunnels, it is considered improbable that there would be impacts due to perceptible vibration within buildings above tunnels.

The aim of the measurements summarised in part 2 was to identify whether road traffic within tunnels is a potential source of groundborne vibration disturbance for receptors located over tunnels. The measurement results from the two different tunnel locations and types confirm groundborne vibration from road traffic within tunnels for receptors located above a tunnel is unlikely to result in disturbance for receptors.

The measurement results from the location adjacent to the carriageway were well below perceptible levels, supporting the conclusions of the literature review in the first part of this task, that under ‘normal conditions’ groundborne vibration may be scoped out of assessment.

It is considered that the measurement results presented here provide sufficient evidence to scope out the assessment of groundborne vibration for receptors; located above road traffic tunnels and located adjacent to the carriageway.

4. Recommendations

Considering the outcome of the literature review together with the supporting vibration measurements support the HD213/11 approach of scoping out the groundborne vibration assessment of existing roads under normal conditions, including receptors over tunnels. Where a scheme involves variation from normal conditions then groundborne vibration should be considered in each case.

The following text is proposed for use in the future version of HD213/11.

“In the case of the assessment of changes to existing roads the assessment of groundborne vibration may be scoped out where conditions are normal. Normal conditions comprise a road with free-flow traffic conditions and where the road surface is smooth and continuous. The road source and receptors should be at similar elevations. The assessment of groundborne vibration may be scoped out where receptors are located over tunnels. For the assessment of situations that fall outside of normal conditions, including where roads are elevated on structures, or where receptors are more sensitive to vibration than residential dwellings, then groundborne vibration should be considered on project specific basis.”

5. References

British Standard 5228-2:2009+A1:2014 – Code of practice for noise and vibration control on construction and open sites. Vibration. (BS 5228-2)

British Standard 6472-1: 2008 – Guide to evaluation of human exposure to vibration in buildings: Part 1 – Vibration sources other than blasting (BS 6472-1)

British Standard 7385-2: 1993 - Evaluation and measurement for vibration in buildings: guide to damage levels from ground borne vibration (BS 7385-2)

Hunaidi, O. and Tremblay, M. Traffic induced building vibrations in Montréal. Canadian Journal of Civil Engineering, Vol. 24, No. 5, 1997, pp. 736–753. (Hunaidi and Tremblay)

International Organization for Standardization 2631: 1989 – Evaluation of human exposure to whole-body vibration. Part 2: Continuous vibration and shock-induced vibration in buildings (1-80Hz). (ISO 2631-2)

International Organization for Standardization 4866:1990 – Mechanical Vibration and Shock. Vibration and buildings: guidelines for the measurement of vibrations and evaluation of their effects on buildings. (ISO 4866)

International Organization for Standardization 8041:1990 – Human response to vibration. Measuring instrumentation. (ISO 8041)

JACOBS, (April 2016), M6 Junctions 16 to 19 Smart Motorway Baseline Vibration Monitoring Report (Jacobs 2016)

Watts, G.R. (1990). Traffic induced vibrations in buildings. TRRL RR246, Transport and Road Research Laboratory, Crowthorne. (RR246)

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