# Groundborne vibration arising from construction works and potential associated impact on ground stability.

**Introduction**

The Environmental Impact Statement (Chapter 9 and Appendix H2 and H3) predicts levels of vibration arising from the tunnelling operation and presents an assessment of how the vibration levels will decay with increasing distance from the Tunnel Boring Machine (TBM). It concludes that the level of vibration at houses nearest the tunnel trajectory is estimated to be approximately one fifth of the vibration caused by e.g. a truck passing by on a smooth road at a distance of 15 m from the house, and considerably lower than the threshold for human perception of vibration.

Human beings are known to be very sensitive to vibration, with the threshold of perception typically in the ppv range of 0.14-0.3mm/sec.

Concerns have been raised about the potential for vibration generated by the TBM to affect ground stability and cause a landslide/peat slide, either alone or in combination with other vibration sources such as construction traffic. This note summarises the potential sources of vibration, and predicts vibration levels caused by sheet piling in the tunnelling compounds, and in the event of a surface intervention pit in Sruwaddacon Bay (Appendix A).

The note also presents results of vibration measurements carried out as follows:

- Baseline underwater vibration (Sruwaddacon Bay) (Appendix B);
- Underwater groundborne vibration associated with borehole survey (Appendix B);
- Measurement of groundborne vibration at Dooncarton Hill during the 2010 ground investigation; and
- Measurement of vibration generated by vehicle movements on the L1202 and L1204 (Appendix C).

**Vibration Measurements during the 2010 Ground Investigation.**

Vibration levels were measured whilst one drilling rig was operational. During the survey the drilling operations were paused for a period, and operations included hammering in order to free the equipment from a temporary blockage.

During the drilling, vibration was measured at three locations: adjacent to the radar station at Dooncarton (R1), adjacent to the cemetery at Pollatomish (R2), and at the Landfall site (R3).

A triaxial array of sensitive accelerometers was placed on an existing solid block of concrete embedded in the terrain at each location. Vibration and noise were measured for a period when the rig was operational. Measured vibration levels were low throughout the measurement period and there was no measured vibration that was attributable to the drilling rig discernable above other local sources of vibration.

Under water vibration measurements have also been conducted in Sruwaddacon Bay during the 2010 ground investigation. Results are presented in Appendix B.

**Vibration generated by Vehicle Movements**

Baseline vibration levels along properties on the L1202 are presented in Table 9.7 of the EIS. In addition, levels of vibration associated with the passing of a truck convoy comprising 5 HCVs were measured at a location in Pollatomish (Appendix C). The measured values (PPV) were analysed and the potential vibration levels from the passing of such a convoy at various distances have been predicted through modelling. The results are summarised in Table 1 below.

**Table 1 Measured & Predicted Vibration from Truck Convoy Exercise**

| **Source distance from road (m)** | 5 | 100 | 300 |
|---|---|---|---|
| **Measured ppv (mm/s)** | 0.38 | | |
| **Predicted ppv (mm/s)** | | 0.085 | 0.049 |

**Vibration generated by Sheet Piling**

Additional vibration can be expected from construction related activities such as sheet piling at the Aghoos and Glengad compounds. Calculations have been carried out to analyse the typical vibrations generated by these sheet piling operations.

The predicted vibration levels from sheet piling at the construction compounds and from an intervention pit in the bay are listed in Table 2 below.

**Table 2 Predicted Vibrations from Sheetpiling Operations**

| **Vibration Source** | **Predicted vibration level at nearest house** | | **Predicted vibration level at Dooncarton Hill** | |
|---|---|---|---|---|
| | **Distance (m)** | **Level ppv (mm/s)** | **Distance (m)** | **Level ppv (mm/s)** |
| Glengad compound sheet piling | 230 | 0.1 | Approx 1000 | 0.02 |
| Aghoos compound sheet piling | 300 | 0.02 | Approx 4000 | 0.005 |
| Sruwaddacon Bay intervention pit sheet piling | 234 | 0.1 | Min 1000 | <0.001 |

**Geotechnical Slope Stability Analysis**

Stability analysis has been performed to assess the potential effects of vibration on the Dooncarton Hill slopes and slopes along the route corridor. The effects of vibration on a slope are assessed using seismic loading in accordance with Eurocode 7 and Eurocode 8. This applies a force onto a soil equal to a proportion of gravity (g) and acts as an additional load on the soil which may impact on the stability of slope. In this case horizontal acceleration has been used in the stability calculation.

The purpose of the analysis was to determine the Factor of Safety (FoS) of the peat slopes using an infinite slope analysis. The FoS provides a direct measure of the degree of stability of the slope. An FoS of less than unity (=1) indicates that a slope is unstable, a FoS of greater than unity indicates a stable slope.

The acceptable safe range for FoS typically ranges from 1.3 to 1.4. The code of practice for earthworks BS 6031:1981 (BSI, 1981) and updated in 2009 to address the Eurocode, provides advice on design of earthworks slopes. The code states that for a first time failure, the design FoS should be greater than 1.3. The slope stability analyses have been carried out using this traditional global FoS for slopes. This (BS 6031) global FoS is equivalent to Eurocode 7 (EC7) FoS, where a computed FoS for a slope of unity or greater satisfies the requirements of EC7.

Approximately 40 shallow slope failures occurred on Dooncarton Mountain during 2003, as a result of an isolated extreme rainfall event. As there is not a significant thickness of peat on Dooncarton Hill, these failures were all relatively shallow in nature. The thin peat cover is still extensive across the northern and north-eastern slopes of the mountain.

As part of the vibration studies, peak particle velocity (ppv) values and peak acceleration (rms) have been predicted. To use these predicted values in a geotechnical slope stability analysis, the peak acceleration is expressed as a fraction of gravity, (ah/g). Typically ppv and rms are expressed in mm/sec, with (g) expressed in m/s. As such, values of (ah/g) are typically extremely small, in the range of 0.0001 to 0.0018.

To calculate the stability of the slopes, Talren slope stability software was used. The Dooncarton Hill slope was modelled using a 25 degree slope with 0.75m of peat overlying a cohesive material. The groundwater level was conservatively assumed to be level with the ground surface. The analysis indicated an acceptable factor of safety of greater than 1.3.

Analyses carried out for the ground conditions along the route corridor used a typical slope of 3 to 5 degrees, with a peat depth ranging from 1.5m to 4.0m and overlying a cohesive material. These parameters are based on site measurements. Values of 0.0001 and 0.0002 (ah/g) were used to represent the background seismic conditions of the area and values of 0.04 (ah/g) were used in the analyses relevant to the predicted vibrations as a result of sheetpiling operations. The analyses indicated an acceptable FoS of greater than 1.3 and hence is not considered a risk in accordance with BS 6031:1981 (BSI, 1981).

**Northern Shore of Bay**

An assessment has also been carried out along the northern shore of the bay. The closest location to the tunnel alignment where peat exists is approximately 250m, at approximately CH86660. The stability assessment of the ground conditions in the context of all of the possible construction activities, including compounds and intervention pits, indicate a FoS well in excess of 1.3 as required by the code.

**Conclusion**

Vibration measurements undertaken at Dooncarton Hill have confirmed that there is no measureable contribution to vibration at Dooncarton from the borehole activities in Sruwaddacon Bay. The predicted levels of vibration arising from construction activities such as sheet piling in the tunnelling compounds, or an intervention pit, will not affect the nearest houses and will be negligible at Dooncarton. Likewise, ground borne vibration arising from tunnelling activities will, at local properties, be lower than vibration generated by ordinary road traffic in the area and will not be perceptible at the nearest house. Vibration from tunnelling does not have the potential to affect ground stability at Dooncarton or any slopes along the corridor of the tunnel through the bay.

Due to the low levels of vibration predicted, in combination with the intermittent nature of the activities, the potential for a cumulative effect is unlikely. In the unlikely event of such a combined effect, the resulting impact would be negligible. In order to set the above conclusions into the context of typical vibration levels generated by everyday activities, please refer to Table 3.2 of 'Environmental Management Guidelines in the Extractive Industry (Non-Scheduled Minerals)', EPA, 2006, data from which are provided below:

| Vibration level | Description of Activity |
|---|---|
| 1.0-2.5 mm/s | Walking measured on a wooden floor |
| 2.0-5.0 mm/s | Door slam, measured on a wooden floor |
| 12-35 mm/s | Door slam, measured over a doorway |
| 5-50 mm/s | Foot stamp, measured on a wooden floor |