TECHNICAL NOTE

DATE:	11 October 2024	**CONFIDENTIALITY:**	Public
SUBJECT:	HGV Vibration Impact Assessment		
PROJECT:	Dinah's Hollow	**AUTHOR:**	Sam Rhodes
CHECKED:	Ben Ward	**APPROVED:**	Mark Easton

1 INTRODUCTION

1.1 WSP UK Ltd (WSP) have been commissioned by Dorset Council (DC), the Client, to undertake an assessment to determine the impact of Heavy Goods Vehicles (HGVs) on the stability of the slopes at Dinah's Hollow.

1.2 During design development of the stabilisation scheme, residents of the area including those in Melbury Abbas, raised concerns regarding HGVs using the holloway, producing vibrations resulting in slope instabilities within the holloway.

1.3 The scope of this technical note is:

- To provide a background in the principal mechanisms affecting of slope stability;
- Define the methodology used as part of the impact assessment; and,
- To provide commentary on the results of the assessment in the context of the scheme.

1.4 Supplementary information relating to the scheme is provided within the following documentation:

- Scheme Options Report – Issue 2 (2014) Parsons Brinckerhoff (now WSP) [1]; and,
- Updated Options Statement Technical Note – Revision 2 – WSP (2024) [2].

2 LANDSLIDES AND SLOPE INSTABILITY

2.1 Landslides and slope failures can have several causes such as: geological, morphological, physical and human. However, to initiate a failure there will be a trigger. A trigger in this context is defined as an external stimulus, such as an intense rainfall event, earthquake or an unplanned excavation, which results in the occurrence of a slope failure.

2.2 Triggers typically result in an almost immediate failure event by causing one on the following stress conditions:

- Rapidly increasing load conditions and/or stress on *in situ* slope material;
- Excavation or removal of material from the slope which adversely impacts slope stability (i.e. undermining or excavation of slope toe); and,
- Significant weather events or interventions which alter the groundwater or surface water conditions.

2.3 In practice, the majority of landslides and slope failures in the UK are as a result of changes in the groundwater or surface water regimes, with a strong correlation between rainfall events and slope failures.

2.4 A smaller proportion of slope failures can be attributed to other causes such as:

- Changes to the geomorphology of slopes;
- Natural weathering of geological materials;
- Long-term dissipation of slope pore water pressures; and,
- Vibration, in a very small number of cases.

2.5 It should be noted that the effects of vibration due to vehicular traffic were not determined to be a root cause of instability within Dinah's Hollow, and as such were not considered within the 2014 Options Report [1]. The report highlight the following mechanisms as the principal causes of slope instability within the hollow:

- Overground surface water flow eroding and weakening near surface slope material;
- Over steepened slopes from historical human erosional processes; and,
- Erosion of the soft verge/slope toe by vehicle movements.

2.6 Due to the trigger mechanisms, identified in Section 2.5, a back analysis of slope stability indicates that the site in its pre-remediated condition is already unstable, without additional consideration for the effects of vibration. Therefore, an assessment on the impact of vibration is not considered applicable for this scenario and therefore has not been undertaken.

2.7 To mitigate concerns regarding vibrations due to HGVs, an impact assessment has been undertaken considering the site in its condition following completion of the proposed soil nailing stabilisation works.

3 IMPACT ASSESSMENT METHODOLOGY

3.1 The objective of this analysis was to determine the proposed design solution (i.e. soil nailing), provides sufficient robustness to resist adverse impacts caused from vehicular movements.

3.2 To assess the impact of HGV vibrations on slope stability at the site, a quantitative analysis was undertaken using the GeoStudio SLOPE/W software package. A staged pseudo-static effective stress analysis was undertaken in accordance with guidance provided by Geo-Slope Ltd [3].

3.3 It should be noted that this impact assessment has been undertaken independently of the geotechnical detailed design of the slope stabilisation measures. The effects of seismic loading and vibration effects were not considered as part of the detailed design, and consideration was not given to BS EN 1998-1 [4].

3.4 The impact of vibration was modelled by inputting a horizontal pseudo-static seismic coefficient (K_h), for each scenario, with the change in Factor of Safety (FoS) observed with increasing K_h.

3.5 It should be noted that a vertical pseudo-static seismic coefficient (K_v) has conservatively not been assumed in these analyses. This is due to vertical seismic forces counteracting the adverse effects of the horizontal seismic forces, by increasing the normal force and thus the shearing resistance of the material in the analysis [3].

3.6 A K_h value range of 0.0005 to 0.2 was used, based on observations of vehicular trafficking by Hunaidi (2000) [5]. It should be noted that a value of 0.2 is considered a high magnitude and not representative of typical vehicular movements. For reference, seismic hazard modelling undertaken by Mosca et.al (2022) [6], indicated that based on a 2,475-year return period, the peak ground acceleration (PGA) likely to occur due to a seismic (earthquake) event within the Dorset region was 0.04g.

3.7 Furthermore, in the context of modelling seismic events in geotechnical design, as part of the pseudo-static stability analysis, Griffin and Franklin (1974) recommend using a K_h equal to one-half the PGA (i.e. 0.02) [6].

3.8 Based on the industry guidance referenced above, the following K_h values were assessed: 0.0005, 0.005, 0.02, 0.1 and 0.2. Intermediary values were also used to assess the change in utilisation of the slope with increasing vibrational effects.

3.9 The following methodology was adopted for the assessment:

- Existing slope stability analysis from soil nailing detailed design was used to identify the critical cross section at the site following stabilisation based on the following criteria:
  - FoS post stabilisation;
  - Over steepened slope geometry; and,
  - Number and length of reinforcing elements (i.e. soil nails).
- SLOPE/W models were set up based on the critical cross sections identified, using a staged pseudo-static effective stress analysis method;
- All reduction factors for geotechnical materials and imposed loads were set to unity i.e. serviceability limit state (SLS);
- Five scenarios were assessed varying the pseudo-static seismic coefficient (K_h) to assess the changes in slope stability with increasing vibration loads based on industry guidance (see Section 3.8); and,
- An additional model using a static effective stress analysis was analysed as a control to assess against the variance in K_h values.

4 CONCLUSIONS

4.1 Under SLS conditions, all values of K_h analysed resulted in a FoS greater than 1. Therefore, is has been determined that the soil nailed solution provides suitable robustness against the risk of vibrations due to vehicle trafficking.

4.2 Based on the K_h values understood to be consistent was vehicular trafficking (0.0005 – 0.05), no significant change in slope stability was observed from the results of the analysis.

4.3 This was found to be consistent with other industry studies into the affects of freight vibrations on slope stability, where other primary triggers, typically rainfall events, were determined to be the root cause of slope stability issues [7].

4.4 In conclusion, the results obtained from the impact assessment determined that the affects of HGV traffic and its associated vibrations shall not adversely impact the stability of the stabilised slopes.

REFERENCES

[1] Parsons Brinckerhoff Ltd, “Dinah's Hollow Stabilisation Options Report (Report No. 285400AF-HLT/1 Issue 2),” Parsons Brinckerhoff, Bristol, UK, 2014.

[2] WSP UK Ltd, “Updated Options Statement Technical Note (Revision 2),” WSP, Bristol, UK, 2024.

[3] Geo-Slope International Ltd, “Multi-stage Pseudo-Static Analysis,” Geo-Slope International Ltd, Alberta, Canada, 2024.

[4] British Standards Institution, “BS EN 1998-1:2004+A1:2013 - Eurocode 8: Design of structures for earthquake resistance - General rules, seismic actions and rules for buildings,” BSI, London, UK, 2005.

[5] O. Hunaidi, “Traffic vibrations in buildings,” *Institute for Research in Construction, Construction Technology Update ,* no. 39, pp. 1-6, 2000.

[6] I. Mosca, S. Sargeant, B. Baptie, R. Musson and T. C. Pharaoh, “The 2020 national seismic hazard model for the United Kingdom,” *Bulletin of Earthquake Engineering,* vol. 20, pp. 633-675, 2022.

[7] A. Indelicato, “The Effects of Freight Vibrations on Slope Stability along the SH35, Bay of Plenty East, New Zealand.,” *Journal of Geoscience and Environment Protection,* vol. 8, pp. 335-345, 2020.

[8] M. Hynes-Griffin and A. G. Franklin, “Rationalizing the Seismic Coefficient Method,” US Army Engineer Waterways Experiment Station Geotechnical Laboratory, Washington DC, USA, 1994.