08/01/2021

Title: Practical Geo-Dynamic Assessment of High-Speed Rail Earthworks on the Align Contract (HS2)

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Affiliation: Jacobs UK Ltd

Geotechnical area: Infrastructure Foundations & Earthworks

The Problem

- Critical velocity effects are excessive ground movement or vibration caused by a train approaching the Rayleigh wave velocity (V_R) of the underlying track/ground. There is no codified method for design.
- The amount of guidance is limited, so the designer must seek a balance between the rigour of academic research and the time/data practicalities of a project.
- Cannot complete a full critical velocity assessment as that involves the track structure, therefore must focus on the geo-dynamic assessment to predict V_R of the completed earthworks. This is mainly influenced by the shear wave velocity (V_S) of the natural ground, placed fill and foundation treatment, and the effect of ground improvements. At the time of design only the V_S of the existing ground is measurable.
- Earthworks construction cannot be controlled using geophysics (V_S).

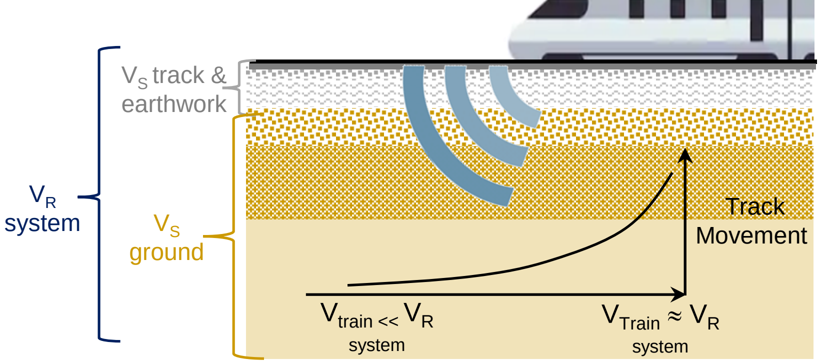

Figure 1 – Schematic of the velocities involved in geo-dynamic scenarios, and how the relative relationship between train and system velocities effects track movement.

Figure 2 – Geophysical testing on the HS2 Align Contract trial embankment, close-spaced geophones to target shallow layers.

The Solution

- Investment in GI is fundamental – requires well-designed geophysics, seismic CPT and good understanding of wider ground model.
- Phased assessment - Initially the V_S of each layer is measured/predicted, and areas of no, or very shallow, treatment identified. Then, to minimise deep treatment where necessary, a dispersion curve is produced from V_S to predict V_R.
- Trial embankment enables an understanding of the full stiffness, V_S and compaction criteria required to design the earthwork fill material specification.

The Contribution

- Process developed to assess cuttings, embankments and at-grade sections. Successfully delivered first geo-dynamic assessment of an HS2 contract.
- Route assessed and treatment depths identified to prevent geo-dynamic effects. Clay strata, Head deposits and Alluvium required treatment. Co-ordinated approach utilised for Foundation Treatment design, so that one solution addresses all settlement, slope stability and geodynamic requirements.
- Inspection & Test Plan includes requirements to clarify remaining areas of potential concern, which minimises unnecessary ground treatment.
- Innovative trial embankment – binder content and material specific plate load criteria assessed, to provide construction controls to meet V_R.

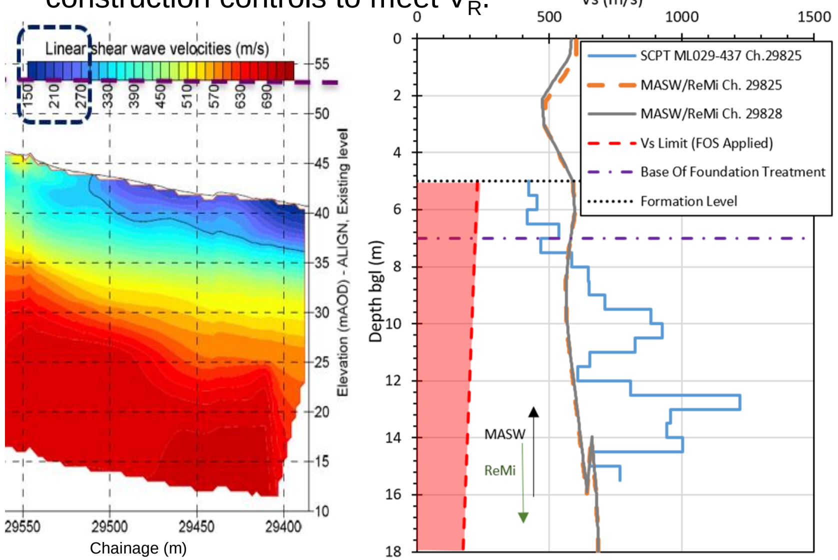

Figure 3 – Geophysical measurements at a mainline ‘poor’ location (left). Assessment of V_S profile from various sources at a ‘good’ location, against developed target criteria (right).

References:

Kaynia, A.M., Madshus, C. and Zackrisson, P. (2000) 'Ground vibration from high-speed trains: Prediction and countermeasure', *Journal of Geotechnical & Geoenvironmental Engineering*, 126(6), p. 531.

HS2 Ltd. (2020) Technical Standard – Earthworks. Document Number HS2-HS2-GT-STD-000-000001

14/01/2020

Title: Engineering mitigation of a water bearing fissure in the Chalk

Name of author: Emily Riley

Affiliation: CVB JV Tideway East

Geotechnical area: Site Investigation and Groundwater Control

The Problem

- A shaft being sunk into Chalk was predicted to intercept a steeply inclined water bearing fissure intercepting the base of a diaphragm wall (D-wall) shaft at 66mbgl. Lateral and vertical extent of fissure unknown.
- Baseline pumping tests >14 l/s, limited by discharge consents. Maximum possible water inflow rates unknown but postulated to be in excess of 80 l/s.
- Programme and equipment constraints meant that increasing diaphragm wall depth would not be possible.
- Additional investigation was required to confirm mitigation options to allow safe and successful shaft internal excavation.

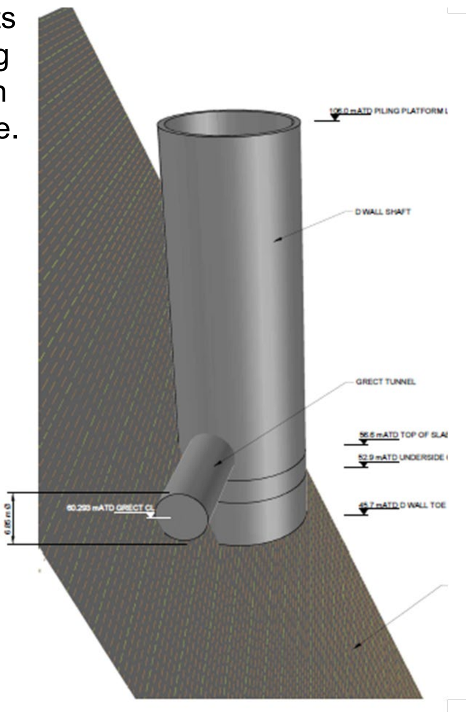

Figure 1 – Schematic of suspected feature on completion of contractor ground investigation (Golder, 2018).

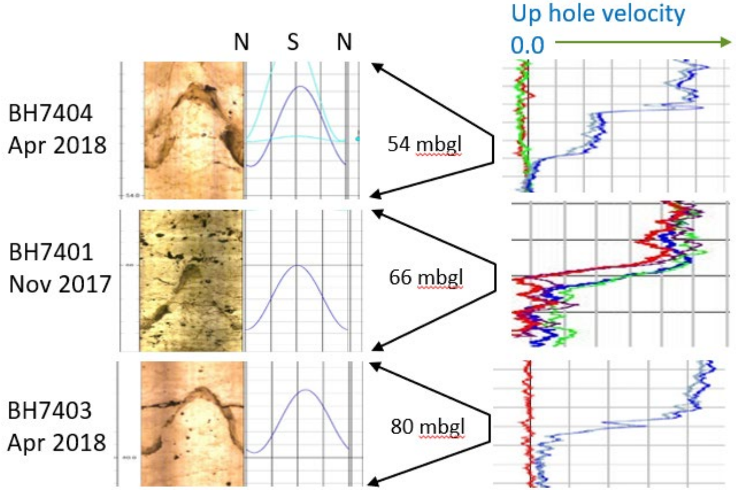

Figure 2: Borehole geophysics: Image and Fluid logs (EGS / WJUK, 2018)

The Solution

- Pumping tests, pumped borehole geophysics and geological logging North and South of the initial interception of the feature delineated the fissure plane.
- Confirmation of inflow. D-wall at planned depth would not provide an effective cut off.
- Targeted grouting inside shaft footprint, using known points of interception prior to D-walling.
- Verification via post D-walling pumping tests and coring through the base of D-wall to verify grouting extent

The Contribution

- Inflow from fissure identified at the expected depths within additional boreholes, confirming feature.
- A grouting campaign using cement-based grouts utilised the known points of interception. Injection of 20m³ of grout which accounted for 38% of predicted fissure infill if a continuous planar feature 50mm wide across the full shaft diameter was assumed.
- No additional mitigation works required to permit shaft excavation, minimising programme impact.
- Logging of marker horizons during borehole drilling and shaft excavation indicated offsets of >1m, which may have been overlooked if geophysical data not available.
- The fissure investigations highlighted the importance of undertaking integrated investigations, and enabled an efficient grouting campaign.

Figure 3 – Identification of grout within fault zone. Confirmed by materials testing

References:

Mortimore, R.N., Newman, TG, Royse, K, Scholes, H and Lawrence, U (2011). *Chalk: its stratigraphy, structure and engineering geology in east London and the Thames Gateway.* Quarterly Journal of Engineering Geology and Hydrogeology. Vol 44.

Stanley, M. et al. (2012). *Design and construction of the Thames Water Lee Tunnel shafts, London*. Tunnels and Tunnelling International, April 2012, 103-108.

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Title of presentation: Clay Cut Slope Deterioration
Name of author: Dr. Harry Postill
Affiliation: Loughborough University
Geotechnical area: Numerical Modelling and Slope Stability

The Problem

- High-plasticity clay infrastructure earthwork assets are deteriorating due to seasonal pore water pressure cycles causing seasonal ratcheting.
- The mechanism of seasonal ratcheting and long-term behaviour of slopes due to different weather patterns (i.e. climate change) is not well understood.
- Understanding slope deterioration rates and where slopes are within their life-cycle is critical for earthwork asset management strategies (see Figure 1).

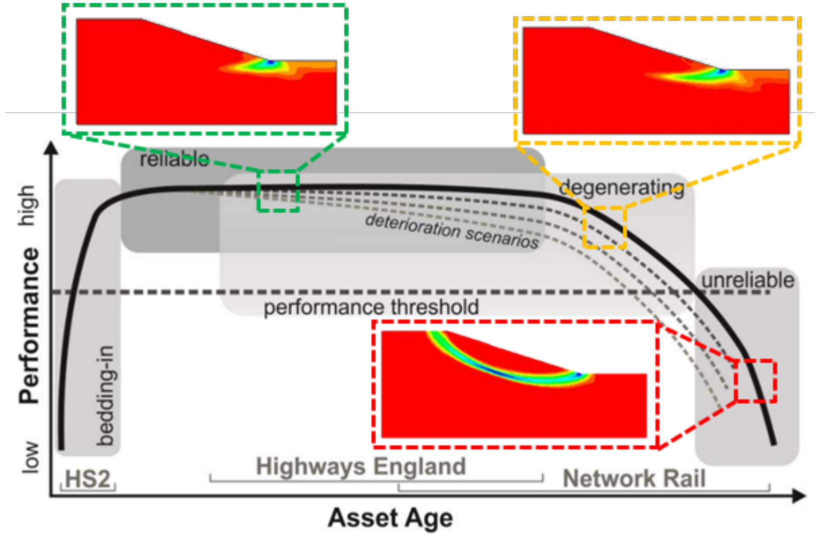

Figure 1 - Generalised deterioration model for transport earthworks (after Glendinning, *et al.*, 2015)

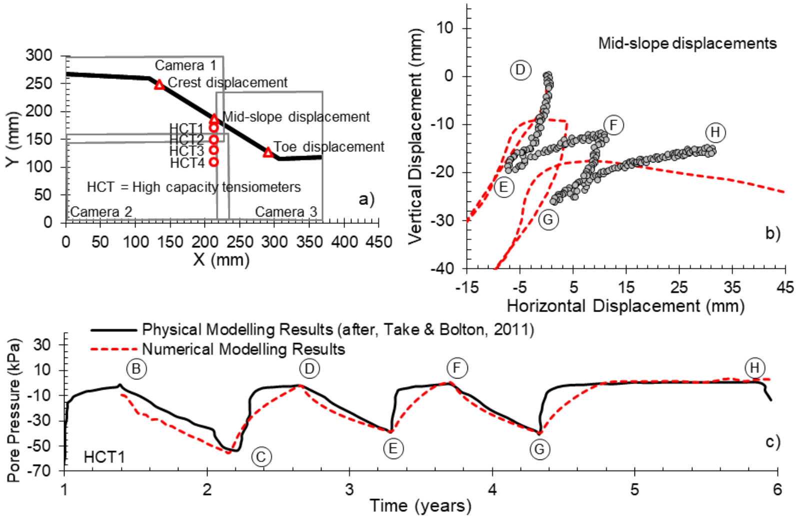

Figure 2 – Validation of numerical model behaviour against centrifuge experimentation (after Postill et al. 2019)

The Solution

- Validated numerical modelling approaches can be used to investigate long-term slope behaviour.
- The mechanism of seasonal ratcheting (i.e. hydrogeological stress cycles causing displacements and progressive failure have been captured in the modelling approach presented.

The Contribution

- Seasonal wetting and drying stress cycles can lead to mobilisation of post-peak strength and progressive failure in clay slopes.
- Seasonal stress cycles will change due to climate change. We have looked at the effect of different weather sequences on slope behaviour and shown that failure occurred earlier in a model considering climate change (i.e. wetter winters and drier summers) (see Figure 3).

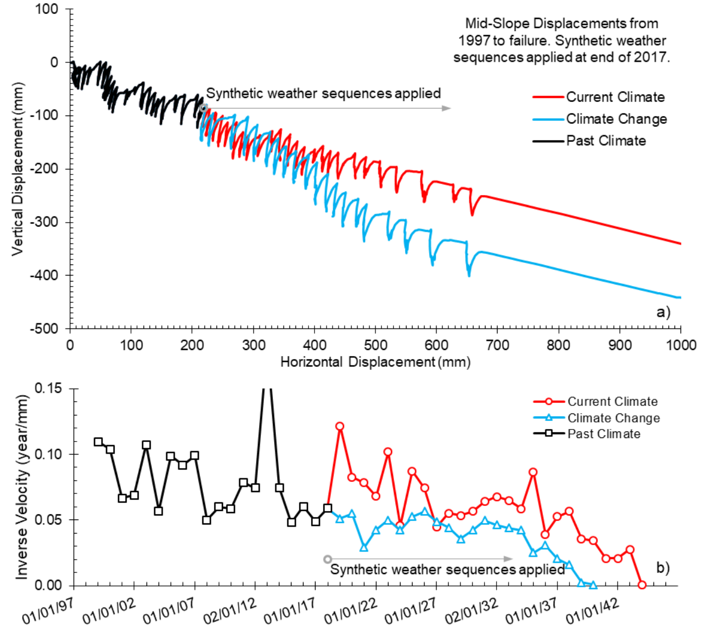

Figure 3 – Effect of climate change on slope behaviour

References:

Glendinning, S. et al. (2015) Research-informed design, management and maintenance of infrastructure slopes: development of a multi-scalar approach. In: *IOP Conference Series: Earth and Environmental Science 26 (2015)*. IOP Publishing, 012005.

Postill, H. et al. (2019) Modelling seasonal ratcheting and progressive failure in clay slopes: a validation. *Canadian Geotechnical Journal.*

Take, W. A. & Bolton, M. D. (2011) Seasonal ratcheting and softening in clay slopes, leading to first time failure. *Géotechnique*, 61(9) 757-769.