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A combined remote sensing - geotechnical modelling approach for fine-scale landslide hazard assessment

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Engineered slopes, including embankments and cuttings, comprise a significant portion of road and rail network infrastructure. These slopes, which are commonly referred to as earthworks, form a core part of the transport system and their integrity is fundamental to overall performance and profitability. However, as is the case with natural slopes, embankments and cuttings can be susceptible to instability and failure, through processes such as landslides. This presents a major challenge for management bodies, generating a constant requirement for earthwork condition appraisal. Typically this is achieved through on-site inspection, carried out by trained engineers. Although effective, this approach is labour-intensive and often hazardous. Whilst geotechnical and geophysical investigation techniques can be extremely effective in providing additional, detailed sub-surface information, their use is normally reserved for high priority sites of limited spatial extent. Airborne remote sensing offers excellent spatial coverage and is able to provide a range of valuable information on surface conditions. Despite this, the use of remote sensing techniques for earthwork assessment remains largely restricted to the provision of supplementary background information – e.g. aerial photographic interpretation. However, in recent years, techniques such as airborne lidar have matured considerably and are now able to deliver high quality information at the high spatial resolutions necessary for engineering-scale slope analysis. The research presented here aims to harness the potential of airborne remote sensing for fine-scale slope hazard assessment. Through a novel modelling approach, this research integrates surface and sub-surface datasets, combining geotechnical monitoring data with airborne remote sensing in order to quantify slope failure hazard at high spatial resolution along a transport corridor test site.

The research has been applied to a real-world rail route located in the north of England, UK. High resolution airborne lidar was acquired for the test corridor and processed to extract a digital terrain model. Multispectral aerial imagery was also captured, using a Compact Airborne Spectrographic Imaging (CASI) sensor, with a pixel resolution of 0.6 m. These datasets provided the basis for extraction of key slope stability parameters, including slope gradient, vegetation coverage, and the topographic wetness index (TWI), with the latter enabling characterisation of soil moisture distribution. These parameters were then embedded in a numerical modelling approach. This utilises geotechnical site monitoring data in order to configure a coupled hydraulic-geotechnical model. The model is parameterised with the remote sensing derivatives in order to simulate response under a range of vegetation and slope scenarios. Current and future climate conditions are also accounted for in the modelling in order to investigate the effects of potential climate change. As output, the model generates slope factor of safety values, which are then linked to the remote sensing parameters through regression analysis, which underpins mapping of slope failure hazard across the test corridor. Software was developed in Matlab to enable slope metrics and results to be plotted and queried on the basis of cross-section profiles. The results indicated that in keeping with field observations, the test site is largely stable. This broadly agrees with the management company's own datasets. Results of the climate modelling indicated that the earthworks are likely to become increasingly stable under future conditions (year 2080) due to longer, drier summers. To summarise, this research has developed a novel approach which is able to quantify slope failure hazard at fine-scale by integrating sub-surface geotechnical information with surface remote sensing datasets. Ultimately, this offers a practicable means of remotely assessing slope hazard at network scales, and prioritising high risk regions for detailed site inspection. Further research will focus on transferability aspects, including sensitivity to modified geotechnical parameters and regional geologies.