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Management appraisal, condition assessment & remedial treatment for ageing Infrastructure earthworks

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ABSTRACT

Embankments and cuttings perform an important function in the efficient operation of an infrastructure network for railways and highways and it is essential that they are recognised within the asset management framework. In 2003 two Construction Industry Research and Information Association (CIRIA) guides were published in the UK on Infrastructure Embankments and Cuttings - condition assessment and remedial treatment, the research for which was carried by Mott MacDonald in partnership with Cementation Skanska and the Transport Research Laboratory Ltd. These CIRIA guides were published with the aim to increase awareness of cuttings and embankments as civil engineering structures and to promote the managerial and engineering requirements of these key assets. This was done in response to a series of failures. As the materials within these structures age, there often develops a need to undertake proactive maintenance of these earthworks, to prevent or minimise the impact of any failures. Since this publication, there has been more focus in the UK in terms of both earthworks engineering assessment and asset maintenance particularly by major infrastructure asset owners. This paper will discuss the asset management measures developed and the associated benefits, with particular reference to the UK Highways Agency Geotechnical Database Management System, developed by Mott MacDonald and Keynetix. Parallels will then be drawn to infrastructure earthworks in Australia and how the lessons learned and developments in the UK can benefit the industry in Australia and prevent similar failures occurring in Australia.

Keywords: Asset management, earthworks, infrastructure, data management

1 INFRASTRUCTURE EARTHWORKS ASSET MANAGEMENT

Infrastructure earthworks (embankments and cuttings) form an integral and important part of most transportation networks, but were traditionally somewhat overlooked as assets that required ongoing management and maintenance after construction. In road and rail infrastructure, the emphasis was traditionally on the maintenance of the pavement, track and structures elements, with earthworks (and often their associated drainage) being mostly managed in an entirely reactive manner, with repairs undertaken at the point at which they have failed and no longer perform their desired function.

In 2003, CIRIA in the UK published two important documents on Infrastructure Embankments (CIRIA, 2003a) and Infrastructure Cuttings (CIRIA, 2003b) that sought to redress this balance and provide guidance on the management, condition appraisal and repair of these geotechnical assets. Core to the recommendations presented in these documents was the recognition that many infrastructure asset owners around the world are responsible for earthworks that are showing accelerating rates of failures as they increase in age. This is particularly noticeable for the owners of younger earthworks, such as those of the motorway and major road networks of many countries. These owners have enjoyed generally good performance from their assets to date (which were designed to more modern standards than many of the older transport networks such as the railways, that can be over a hundred years old).

The CIRIA reports also demonstrated the importance of considering the whole life cost of earthwork asset management. It can be easily demonstrated that reduced overall costs are achievable through a move to the proactive maintenance of earthworks (for example through the improvement of slope
drainage to increase the stability of an earthwork) rather than costly renewals and repairs carried out once an earthwork has failed. These savings are made not only through reduced construction costs, but also through more efficient planning, budgeting and procurement, as opposed to unplanned reactive remedial works (which may need to be undertaken urgently). However, in order to be able to reach a position where such a proactive maintenance strategy is in place, it is essential to first understand your earthworks and their current condition (in considerable detail), which is not a trivial task for owners of large infrastructure networks.

2 UK GEOTECHNICAL ASSET MANAGEMENT EXAMPLE: THE HIGHWAYS AGENCY

The seminal CIRIA documents on infrastructure earthworks are recognised in the UK as best practice, and, through their examples, they sought to establish principals and procedures that could be adopted more widely by clients and practitioners to bring efficiencies and benefits. The geotechnical asset management activities of the UK Highways Agency (HA) are one such example of best practice that is described in this paper.

The HA is responsible for the operation, maintenance and improvement of the 7050 km of Motorways and Trunk Roads (major ‘A’ roads) in England. They have a diverse range of assets that require management and maintenance; one of the key assets being the geotechnical asset, which comprises both earthworks (cuttings, embankments and acoustic/aesthetic bunds) and sections considered to be at-grade. These assets vary considerably in age (refer to Figure 1), geological conditions, design and construction method. Following peaks in construction of the HA network in the 1970s and 1990s, the road infrastructure is largely complete, and the key activities now undertaken by the HA are centred on network improvement, optimisation and maintenance.

\[\text{Figure 1. Assessed age of the geotechnical assets of the HA road network}\]

2.1 Geotechnical asset management strategy

In order to manage their ageing geotechnical assets, the HA put in place a logical and progressive strategy as follows:

2.1.1 Development of standards

Underpinning the geotechnical asset management strategy of the HA is the HD41/03: Maintenance of Highway Geotechnical Assets standard (Highways Agency, 2003). This document outlines the key aspects of the asset management strategy, and was released to coincide with the national implementation of the asset management system described later. In particular, HD41/03 deals with:

- Required competencies for key geotechnical staff contributing to the maintenance process,
- Asset inspection methodologies and frequencies,
- The risk assessment framework for asset condition,
Workflow and certification procedures for geotechnical maintenance works.

2.1.2 Determination of asset inventory and condition

Determination of the asset inventory, and its detailed condition underpins the entire geotechnical asset management strategy. In establishing this data, the key surveys undertaken are the Principal Inspections, which were initially undertaken on 20% of the network in a Managed Area per year, such that the survey cycle was completed in a five year period. The Principal Inspections collect information that can be broadly described as:

- Inventory information, that can essentially be considered to be static. This includes information such as the location of the asset, geological conditions and slope geometry,
- Condition information, which is time limited and considered to be live, or transient data. This would include observations of a wide range of geotechnical features that may be observed (e.g. tension cracks, subsidence, rock falls) but also other observations that affect the asset, such as water observations (e.g. ponding on the slope, marshy ground).

The collected condition information can be very diverse on a geotechnical asset, and can include features which might be considered to present a risk to the safety or operation of the network, and others that present a lower, or no risk. This variation in the risks presented by the observed observations is addressed through the risk assessment framework set out in the HD41/03 standard, which forms the basis of the prioritization process that delivers the proactive maintenance goal.

2.1.3 Risk assessment and prioritization

During a Principal Inspection, the surveyors are tasked to determine the risk that any identified features (such as indicators of failure, or poorly drained slopes) pose to the performance of the asset. Whilst this risk assessment can be reviewed and approved back in the office, the key decisions are best made in the field, and for this reason surveyors are expected to be qualified and trained to recognise and assess geotechnical problems.

The risk assessment is carried out in a series of stages, which determine two key variables:

- An observation Class is assigned, which is either within:
  - Class 1: defects, including failures and precursors of failure such as tension cracks
  - Class 2: areas considered to be at risk
  - Class 3: areas of previous repair, strengthening or preventative works
- The location of the observation is assessed, relating to the proximity of the feature to the carriageway, or other highway infrastructure. A Location Index is applied, ranging from A (e.g. affecting a carriageway running lane) to D (e.g. remote from the carriageway)

Based on a combination of the observation class and location, a risk level is determined, ranging from negligible risk to severe risk. These risk levels have associated indicative remedial actions as outlined in Table 1.

The risk assessment methodology and the recommended actions outlined in Table 1 are designed to facilitate a proactive approach, whereby preventative works can be undertaken to curtail failures that are in an incipient state now, as indicated by features found during inspections (tension cracks being a very good example). However, the methodology also recognizes that reactive actions may also be required (typically at greater cost) where failures of high risk are identified. The actions outlined in Table 1 are outlined at a high level only. The choice of particular remedial methodologies (good summaries of which are outlined in the CIRIA documents), and their relative whole life costs follow on from the prioritization process.
<table>
<thead>
<tr>
<th>Risk Level</th>
<th>Description</th>
<th>Recommended Geotechnical Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>S</td>
<td>Severe</td>
<td>Remedial action must be undertaken with highest priority and H&amp;S/Traffic Management requirements considered and kept under constant review. Consider value for money of Preventative works on adjacent Class 2 assets and potential impact on other Routine or Capital maintenance activities.</td>
</tr>
<tr>
<td>H</td>
<td>High</td>
<td>Remedial action required, timescale to be determined by the Overseeing Organisation Geotechnical Advisor and Overseeing Organisation Area Manager, but within 5 years. Interim monitoring/inspection may be called for and H&amp;S/Traffic Management requirements considered. Consider value for money of Preventative works on adjacent Class 2 assets and potential impact on other Routine or Capital maintenance activities.</td>
</tr>
<tr>
<td>M</td>
<td>Medium</td>
<td>Remedial action may not be required but preventative action advisable within 5 years. Review inspection and/or monitoring regime and potential impact on other Routine or Capital maintenance activities.</td>
</tr>
<tr>
<td>L</td>
<td>Low</td>
<td>No immediate action required. Review inspection and/or monitoring regime. Consider value for money of Preventative works. Review potential impact on other Routine or Capital maintenance activities.</td>
</tr>
<tr>
<td>N</td>
<td>Negligible</td>
<td>No immediate action required. Re-inspect in five years.</td>
</tr>
</tbody>
</table>

Table 1: Recommended actions relating to risk levels

2.2 The HA Geotechnical Data Management System (HA GDMS)

Key to progressing the geotechnical asset management strategy of the HA outlined above has been the development and use of the HA Geotechnical Data Management System (HA GDMS), an online, browser based, Geographical Information System (see Figure 2) developed and maintained by Mott MacDonald and Keynetix and provided as a licensed service to the Highways Agency.

![Figure 2: Screenshot of the HA Geotechnical Data Management System](image-url)
HA GDMS was rolled out as a national system in 2002 following a successful pilot. It is an easy-to-use, centralised system that is accessed by all those requiring information on the HA geotechnical asset, whether from within the HA, as a Managing Agent, Design Agent or other party to a geotechnical project. The data and functionality of the system is an integral part of their work and the system is heavily used over 1000 active users from 300 organisations. In 2011 HA GDMS had approximately 2000 logins to the system every month.

HA GDMS comprises of a series of powerful data capture and data quality tools, together with reporting and dissemination and visualisation tools that uses a mapping interface with a series of layers, combined with databases of key geotechnical information to help the user visualise available data. The tools and mapping layers include:

- A Geotechnical Asset Database (GAD), containing detailed inventory and condition information for nearly 45,000 individual geotechnical assets and over 250,000 observations,
- A technical archive of over 13,000 geotechnical reports, including nearly 9000 scanned copies of the reports available to view or download. These reports are stored with key descriptive meta-data, and the scanned copies have had OCR applied, allowing intuitive searching of complete report contents. Each report is geographically linked to the map to allow discovery of reports that are applicable to certain roads or sections of roads,
- Over 100 mapping datasets from a large number of UK suppliers.
- Links to the borehole archive of the British Geological Survey (BGS), 1:625k and 1:50k scale geological solid and drift maps and a reference mapping layer of BGS District Geologists,
- Field data capture software (PocketGAD) that operates on small hand-held computers running Windows Mobile operating system, with links to real time GPS positioning. This software allows surveying data to be captured in the field, with in-built error capture logic, which can then be uploaded to HA GDMS for instant population of the Geotechnical Asset Database. PocketGAD does not rely on an internet connection as signals can be weak around the road network, instead the user can download detailed mapping and aerial photography and previous survey history before they start the survey. This data can be viewed and updated in the field, allowing instant verification of the asset information being collected, or being verified and updated by re-survey,
- Online earthwork visualisation tools allow the managing agents to see every observation and geometry feature of an earthwork on a single graphical schematic,
- Data quality is maximised as far as possible through use of online tools and an approval process that allows self-certification of data by Managing Agents,
- Network status reporting allows the HA users to produce informative summary or details reports on the state of the network and progress against KPIs,
- HA GDMS also links to the HA Drainage Data Management System (HA DDMS), providing users will the ability to display and query all drainage assets and flooding events. The ability to visualize and interrogate information across asset types allowing holistic evaluation of sites is one of the major benefits of a system such as HA GDMS.

Critically, the HA GDMS has been developed by an engineering team, with experience as HA Managing Agents, rather than being driven by the Information Technology that facilitates the tool. Throughout its development, user feedback, through the use of ‘wish lists’ has ensured that enhancements to the system have met the key needs of the HA business and the operational needs of the Managing Agents that make up the majority of its users.

2.3 Benefits

The benefits of successful asset management are manyfold, with key elements being improved service provision to the users of the assets (namely the road users of the HA) and cost savings to the infrastructure owner in meeting the requirements of the user. In the development of the asset management strategy of the HA, and the implementation of the HA GDMS to underpin the strategy, the benefits have included:

1) informing and prioritizing national budgets based on a rational assessment of asset condition and risks posed to the road network
2) improving technical and managerial performance
3) improving value (and reduce costs)
4) improving safety
5) reducing incidents impacting the operability of the road network
6) providing national benchmarks

Conservative estimates of the benefits realised by the implementation of HA GDMS alone have demonstrated that a high benefit/cost ratio has been achieved and that identified benefits though better asset management are in the order of £2M (AUD$3.1M) per annum.

3 AUSTRALIAN INFRASTRUCTURE EARTHWORKS

By comparison to the UK limited infrastructure asset management practices of a similar approach and scale are currently in place in Australia, however the road networks across Australia and other important transport networks such as freight railways, provide a key transport mode and are of equal vulnerability if not more so recently due to extreme rainfall events. The National Road Network in Australia alone covers a length of 22,500 km.

In 2010/2011 numerous roads in Australia were closed for significant periods of time due to the associated impacts of heavy rainfall. In certain areas a lot of road damage was as a result of failures of infrastructure earthworks. Some authorities and local councils have been overwhelmed as a result and the recovery process has been difficult with limited asset management strategy in place.

As a similar example, in the 1970’s Hong Kong experienced significant slope stability issues following an unprecedented wet year and as a result the Geotechnical Control Office (GCO) was formed and the Geotechnical Manual for Slopes published. Similarly in HK a geotechnical asset database (the Slope Information System) is now in place and used to manage proactive slope maintenance in HK.

Structured, risk assessment based geotechnical asset management could enable better network management in Australia and prevent the scale of incidents occurring in future affecting key transport corridors.

4 CONCLUSION

The successful management of ageing geotechnical assets is a considerable challenge, faced by many infrastructure owners around the world. The experience of the Highways Agency in England, provided as an example of best practice, has shown that it is possible to move towards a successful proactive means of managing the asset. Key to the strategy implemented is excellent asset knowledge, held in an accessible and fully feature asset management system such as HA GDMS. The experience of the HA in development of their asset management strategy is applicable to similar transportation asset owners throughout the world.

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