Engineered Soil Slopes Hazard on the Strategic Road Network of England

This guidance note is intended for non-specialists of ground-related hazards and describes the potential for Engineered Soil Slopes to impact the safety and performance of the Strategic Road Network (SRN). Together with the Slopes Hazard Rating map and corresponding hazard assessment note on Highways England's Geotechnical Data Management System / Geographical Information System (HAGDMS / HAGIS), the three products support effective management of the Engineered Soil Slopes risk to the network.

This guidance note does not replace the need for local and site-specific assessment by Highways England's geotechnical specialists.

How to use this guidance note:

Part I: provides an overview of Highways England's risk management of Engineered Soil Slopes hazards
Part II: outlines steps in the risk management framework to enhance the network resilience to Engineered Soil Slopes
Part III: provides further background information specific to Engineered Soil Slopes, its relevance to the SRN, and key sources of reference

Part I Highways England's approach to managing Engineered Soil Slopes risks

Areas adjacent to or in close proximity to Engineered Soil Slopes are susceptible to impacts caused by the failure of the slopes. Engineered Soil Slopes have usually been formed by excavation in the natural topography (cuttings) or constructed by placing fill to form embankments. The background of Engineered Soil Slopes and their impact on the SRN is summarised in Part III.

Soil slope failure, M25 (Highways England)

For hazards associated with Natural Landslides or Engineered Rock Slopes see the corresponding guidance notes.

The risk presented by the failure of Engineered Soil Slopes is not new to Highways England. Any new assessment of the risk should make due consideration of the following factors:

- At the time of construction of the SRN or at the time of undertaking improvement schemes, Engineered Soil Slopes would have been designed according to the standards of the time to be sufficiently stable for their design life. Where available, relevant records are held in HE's geotechnical database held on HAGDMS.
- The Geotechnical Risk Management procedures were introduced in the 1990s. Specifically, *HD22 Managing Geotechnical Risk* was first published within the *Design Manual for Roads and Bridges* (DMRB) in 1992. It is therefore reasonable to assume that for schemes post 1992 there is an improvement in the reliability of information captured and retained, along with increased standardisation in investigation, design, and mitigation methodologies across schemes.

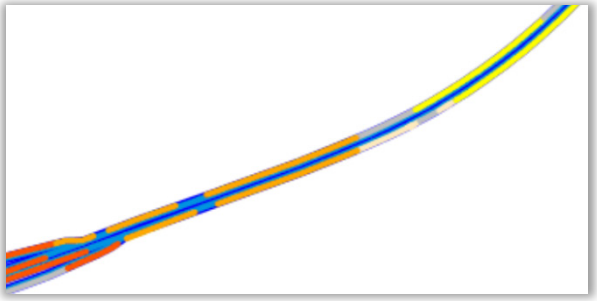
1.0 Current ground risk management requirements:

HD22/08 (DMRB Volume 4) presents a framework for geotechnical risk management and is a mandated requirement on all highway schemes where a ground investigation or geotechnical design is required. It establishes the principles of early risk identification and continuity of the geotechnical risk register through the project life cycle from concept to handover.

HD41/15 (*Maintenance of Highway Geotechnical Assets*) provides guidance on the identification and management of 'At Risk Areas' including those of potential Engineered Soil Slopes related risk. Consideration of the hazard posed by Engineered Soil Slopes to the existing SRN should form a part of the GeoAMP (Geotechnical Asset Management Plan) process. The GeoAMP is prepared by the Operations service provider, reviewed on an annual basis (at a timeframe agreed with Highways England), and is submitted for agreement by HE.

For guidance on the application of current requirements please refer to the Advice contacts below.

2.0 The Highways England Slopes Hazard Rating Map



Section of the Slopes Hazard Rating map

An HE specific Slopes Hazard Rating has been prepared which includes both soil and rock slopes (however a separate rock slope–only map will shortly be available to accompany the Engineered Rock Slopes hazard guidance note). The Slopes Hazard Rating map can be accessed on HAGDMS*. The derivation of this map is explained in detail in a hazard assessment note available on the HA GDMS download page: *HAGDMS Slopes Hazard Rating data description (April 2017).*

The map is intended as a high level hazard awareness map only. **It does not replace the need to seek expert advice** from within Highways England and undertake site-specific studies. As noted above, consideration of Engineered Soil Slopes along with all other ground-related hazards is an inherent part of risk management within Highways England's geotechnical standards.

3.0 Further advice

To obtain further advice on the hazard Engineered Soil Slopes poses to the Strategic Road Network, or for any other issues associated with ground-related hazards, please contact one of the Geotechnical Advisors available within Highways England's Geotechnics and Pavement Group.

Role of Highways England's Geotechnical Advisors:

- Technical oversight of schemes, to ensure the technical input is appropriate, complies with HE standards and delivers good value.
- Cascading local knowledge and good or bad experiences from other projects
- Evaluating and supporting innovation opportunities to promote efficient delivery.
- Providing asset data and information management services.
- Managing knowledge improvement for the geotechnical discipline, including Standards and Advice Notes and supporting Integrated Asset Management in Highways England.

* The latest version of the Slopes Hazard Rating map should be used. Superseded versions will continue to be available on HAGDMS for reference only.

Part II Using the Slopes Hazard Rating map to enhance resilience of the SRN

Resilience of the Strategic Road Network comes from both adequate design and maintenance, mitigation of hazards, and having appropriate response and recovery measures in place should the hazard occur. Selection of appropriate mitigation (proactive, pre-event) measures versus response and recovery (reactive, post-event) cannot be prescriptive, but the guidance below can be used to support risk-based decision making.

1. Define the hazard event

A hazard 'event' can be defined as '*the event that could occur due to the presence of the hazard*'. The following are different hazard events related to the presence of Engineered Soil Slopes adjacent to (cutting slopes) or beneath (embankments) the SRN, and these present different risks to the network:

- Incursion of material onto carriageway (cuttings) – potential obstruction and damage
- Subsidence of part or all of a carriageway, structure or other asset (embankments) – could be sudden or progressive
- Impact damage to structures and above-surface SRN asset due to a moving soil mass / debris
- Instability and damage to sub-surface SRN assets including foundations and buried utilities (e.g. drainage, power, communications)

2. Consider potential external triggers of the hazard event

There may be little or no warning of an Engineered Soil Slope failure, but if specific triggers have been identified, these can be monitored to improve the management of the risk. The following are the main potential external triggers of an Engineered Soil Slopes hazard event:

(A) Natural triggers

- Heavy or sustained rainfall/snowfall – may be during or following the storm event
- Groundwater regime change (refer also to the Groundwater Flooding hazard guidance note)
- A surface flooding event – may also have an man-made underlying cause
- Cyclic natural degradation (e.g. tidal erosion, freeze-thaw cycles, shrink-swell cycles)
- Erosion (surface or groundwater flow)
- Animal burrowing
- Earthquakes

Note that the above water related triggers (surface or groundwater, flooding etc.) may be exacerbated by climate change.

(B) Human activity-related triggers

- Leakage from nearby water mains, sewerage and drainage.
- Change in surcharging or loading
- Removal of vegetation – may be contributing to slope stability
- Degradation / loss in performance of any stabilisation measures such as soil nails or anchors (also see the Aggressive / Corrosive Soil and Groundwater hazard guidance note)
- Water seepage from service duct backfill which may act as a water reservoir
- Human activity nearby (e.g. excavation at toe of slope) – also includes third party activities outside the boundary fence, e.g. changes in ploughing patterns

Highways England Geotechnical Advisors can provide further information of potential triggering actions.

3. Assess the likelihood of the hazard event occurring

The *hazard rating* given on the Slopes Hazard Rating map is not an absolute indicator of the likelihood of a hazard event occurring, but a relative indicator of the potential presence of Engineered Soil Slopes, compared to the rest of the network. The Engineered Soil Slopes hazard rating is not directly comparable to hazard ratings derived for other hazard types.

To undertake a qualitative assessment of the likelihood of slope failure or subsidence related to slope movement (mainly in embankments), the following factors are relevant:

(A) The inherent likelihood of an Engineered Soil Slope failure

- Refer to the Slopes Hazard Rating map
- Evidence of movement (e.g. monitoring or any evidence recorded in Geotechnical Asset Database (GAD), or in Geotechnical Asset Management Plans for known landslide areas)
- Poor slope condition / low inherent stability as indicated a geotechnical slope examination (HD 41/15) – for slope-specific indication of condition
- Age of slope / SRN section – supplementary condition indicator where a geotechnical examination is not available or not recent

(B) Presence of any mitigating / exacerbating features

- Presence, condition and effectiveness of slope improvement / stabilisation measures – as installed during construction / maintenance of the SRN or by third parties
- Size (height / volume) of slope and distance of slope from the SRN – to indicate the context and proximity of the carriageway relative to a potential landslide, and the likelihood that a slope failure would interact with the road network

(C) Indicators that a triggering action (as listed in Step 2: Triggers) is likely to occur

These may be considered by the type of triggering mechanism:

- Water-related inundation / saturation / destabilisation:
  - A history of flooding (also refer to the Groundwater Flooding hazard guidance note)
  - Observed / forecast heavy or prolonged rainfall – the impact of our changing climate on soil slopes is an important consideration. Evidence of past instability alone may no longer be sufficient.
  - Blocked / insufficient / absent drainage
  - Water/wastewater pipes in poor condition, e.g. aged or damaged through construction-induced ground movements and may leak
  - Presence of service ducts or poorly compacted backfill – granular backfills may act as a localised source reservoir (if exposed at the surface / have connectivity with other water sources)

- Loading of slope and undermining slope integrity:
  - Construction, new structures, or temporary plant may indicate loading beyond a stable limit (primarily an issue with improvement schemes)
  - Traffic loading (volume) increases

4. Consider the potential impact on the safety and/or performance of the SRN

A quantitative assessment of impact on a national scale is not possible, but at a local level, the following factors should be considered to understand the potential impact:

(A) Factors specific to the hazard event:

- The rate of failure and the amount of warning available – a rapid, catastrophic failure presents the highest safety consequence.
- The size of the potential failure – impact to the network (damage / obstruction) is linked to the volume of debris deposited from a slope above the carriageway, or area of SRN undermined by a slope failure below the carriageway.
- The location of the potential failure – a landslide impacting a main running lane presents both higher safety impact and higher performance impact than one that affects only a hard shoulder / remote from the carriageway.
- Consideration of potential investigation and remedial works – the longer these could take, the longer the performance impact.

(B) Factors specific to the location of the hazard event on the network:

- The speed and volume of traffic using the road – where higher it typically correlates to an increased safety impact.
- The type of pavement – a sudden/catastrophic failure is more likely where there is loss of support beneath by a rigid pavement whereas a flexible pavement show early signs of a failure (where soil slope supports the SRN)
- The type of road – smart motorways being the most important in terms of performance, down to All Purpose Trunk Roads (APTR) being the least.
- Presence of technology – smart motorways could be assumed better able to respond to an event in terms of traffic management.

5. What is the risk (considering likelihood and impact) that Engineered Soil Slopes presents to the SRN?

This can be qualitatively assessed, and should inform subsequent decision making. Uncertainty should be recognised and decisions should typically be cautious, particularly where there are high levels of uncertainty (or lack of data).

6. Select appropriate measures to mitigate risk and enhance resilience

Measures taken to mitigate risk and enhance resilience may be either proactive or reactive. Typically, the greater the safety or performance risk to the SRN in terms of both likelihood and impact of an event, the greater the benefits of undertaking proactive mitigation. When selecting appropriate measures, there should be early engagement with Geotechnical Specialists from Highways England, service providers and land owners (where the slope is outside the SRN boundary).

High level risk management measures are likely to be specific to both the hazard event and whether it is a construction and/or on-going operations risk, but all measures would fall into one of the following categories:

- **Investigation:** To understand the current condition and therefore likelihood of the hazard event. Investigation may reduce the uncertainty and hence reduce the need for additional mitigation measures. Visual inspections are the primary source of assessment either to identify 'early warning signs' or to evaluate stability when a location is flagged for review (for more information refer to **HD41/15**).
- **Intervention:** Where there is an evident cost-benefit in implementing measures (barriers) to prevent the hazard event from occurring, or mitigating measures to limit the impact should it occur.
- **Monitoring:** To allow appropriate operational responses to be implemented in anticipation of a potential hazard event.
- **Response and recovery:** To respond rapidly to a potentially unexpected hazard event, development of response plans is recommended for areas of known Engineered Soil Slopes risk. Response plans should include:
    i. Engagement with Highways England technical specialists – named focal points (and responsibilities) should be clearly identified.
    ii. Identification of third party land owners where the slope is located outside the SRN boundary, or that will be potentially impacted should an HE-owned slope fail. Also procedures for gaining access where required to third party land.
    iii. Being prepared to close lanes and/or implement diversions, and have an understanding of the potential duration of these measures until the SRN may be fully operational – this includes a broad range of communications, such as Highways England's suppliers, road users and the general public. These should be linked to Incident Response Plans (IRPs).
    iv. Likely response options should be identified – based on the particular hazard events and anticipated consequences. The time and resources that would be required to implement the options should also be considered.
    v. Incident recording – following initial recovery, a full record of the mitigation works (as part of Health and Safety file recording), the cause of the event assessed, the risk of similar events occurring elsewhere on the network evaluated, and appropriate actions taken to manage the incident should be recorded. All geotechnical events must be recorded on HAGDMS.

Part III An overview of Engineered Soil Slopes in England

1.0 Engineered Soil Slopes

Embankment slope failure stabilised with soil nailing, M25 (Highways England)

Engineered Soil Slopes along a road network are typically formed by cutting through a higher topography landscape (soil formation) or by placing fills and forming an embankment. The soil slopes are formed to a suitably stable angle either by consideration of the likely groundwater conditions and their natural properties or properties are altered by stabilisation methods such as the inclusion of reinforcement. Soil slopes are present throughout the SRN.

HAGDMS presents a thematic map layer categorising the Slope Hazard Rating into six ratings (Very Low to Very High, and No rating). The categories are based on an analysis that has been carried out into the performance of the major Geotechnical Assets of Highways England. The latest available version of the Slopes Hazard Rating should be used as it will reflect the most current analysis; however, HAGDMS also retains previous versions of the map for historical reference only (e.g. the 2014 map is available but is superseded.) The derivation of the Slope Hazard Rating is based on the slope shape and geology. This is explained in detail in the note on Slopes Hazard Rating data description on HAGDMS.

2.0 Engineered Soil Slopes and the Strategic Road Network

The hazard posed by Engineered Soil Slopes can be considered to arise from:

- The potential for Engineered Soil Slope failure above or beneath the Highways England estate with the potential to either cause sudden and catastrophic collapse, impede the highway or damage SRN assets. These hazards could be present due to:
  - inadequate design and/or stabilisation methods (compared to current practice/guidance), which may correlate to the age of the slope
  - management of water (surface or subsurface) – blocked, insufficient or inappropriate drainage systems. This could also be caused by changes in water level/flows over time (e.g. due to environmental changes) and that the existing drainage system has not been designed for this.
  - stabilisation measures employed have deteriorated subsequently due to changes unforeseen at the time of treatment (e.g. chemical, groundwater or surface flooding) or have reached the end of their serviceable life

The type of hazard that the presence of Engineered Soil Slopes that are susceptible to failures presents to the SRN is further significantly influenced by the size of the failure and its proximity to the network.

3.0 Key references and further information

Slopes Hazard Rating map, 2017, HAGDMS / HAGIS

HAGDMS Slopes Hazard Rating data description, 2017

Acknowledgement and contact details

This work has been informed by two tasks currently being undertaken as part of HE's Innovation Programme: Task 1-085 *Resilience enhancement measures for geotechnical assets* and Task 1-062 *Geotechnical Hazard Knowledge*.

For further information, queries or comment please contact David Patterson david.patterson@highwaysengland.co.uk