Compressible / Collapsible Ground Hazard on the Strategic Road Network of England

This guidance note is intended for non-specialists of ground-related hazards and describes the potential of Compressible / Collapsible Ground to impact the safety and performance of the Strategic Road Network (SRN). Together with the Compressible / Collapsible Ground 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 Compressible / Collapsible Ground 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 Compressible / Collapsible Ground hazards
Part II: outlines steps in the risk management framework to enhance the network resilience to Compressible / Collapsible Ground
Part III: provides further background information specific to Compressible / Collapsible Ground, its relevance to the SRN, and key sources of reference

Part I Highways England's approach to managing Compressible / Collapsible Ground risks

Compressible ground refers to very soft materials (e.g. peat, alluvium, laminated clays, wind-blown deposits, lightly compacted backfills) that are susceptible to large and progressive settlement when loaded or when the groundwater changes.

Collapsible ground refers to deposits that when weakened through saturation and loaded can undergo rapid volume reduction (its micro-structure crushes).

The background of Compressible / Collapsible Ground and its impact on the SRN is summarised in Part III.

Compressible soil (peat)

The risk presented by Compressible / Collapsible Ground 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, Compressible / Collapsible Ground and related risks should have been investigated and mitigated appropriate to the standards or advice that applied at the time. 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:

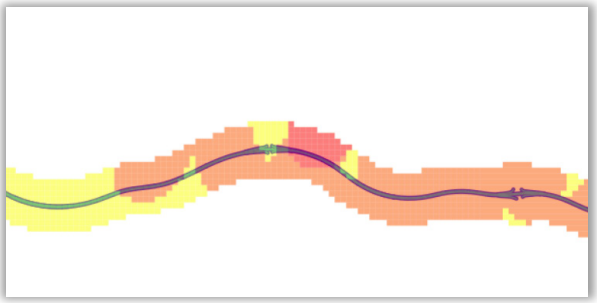
HD22/08 (DMRB Volume 4) presents a framework for geotechnical risk management and is a mandated requirement on all highway schemes where a ground investigation or geotechnical design is required. It establishes the principles of early risk identification and continuity of the geotechnical risk register 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 Compressible / Collapsible Ground related risk. Consideration of the hazard

posed by Compressible / Collapsible Ground 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 Compressible / Collapsible Ground Hazard Rating Map



Section of the Compressible / Collapsible Ground Hazard Rating map

An HE specific Compressible / Collapsible Ground Hazard Rating map for a 1km corridor centred on the Strategic Road Network has been prepared. This can be accessed on HAGDMS / HAGIS. Version 1 of the hazard map is a synthesis of information relating to Compressible / Collapsible Ground obtained from the British Geological Survey (BGS). The derivation of this map is explained in detail in a hazard assessment note available on the HA GDMS download page: *HAGDMS Compressible / Collapsible Ground 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 Compressible / Collapsible Ground 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 Compressible / Collapsible Ground 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.

Part II Using the Compressible / Collapsible Ground 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 Compressible / Collapsible Ground along the SRN, and these present different risks to the network:

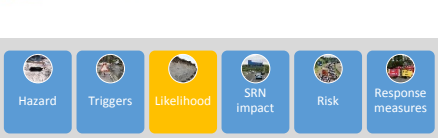
- Collapse of the ground (sudden)
- Subsidence (due to loss of support) or settlement (in response to loading) which can be progressive: they may occur relatively rapidly and also continue long-term

2. Consider potential external triggers of the hazard event

Whilst subsidence of compressible ground is normally progressive with signs of onset, there may be little or no warning when collapsible ground fails. If specific triggers have been identified, these can be monitored to improve the management of the risk. The following are potential external triggers of a Compressible / Collapsible Ground hazard event:

- Change in surcharging or loading
- Groundwater regime change (refer also to the Groundwater Flooding hazard guidance note)
- Leakage from nearby water mains, sewerage or drainage
- Water ingress from service duct backfill which may act as a water reservoir
- Vibration, e.g. due to traffic, construction activities
- A surface flooding event

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



3. Assess the likelihood of the hazard event occurring

The *hazard rating* given on the Compressible / Collapsible Ground 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 Compressible / Collapsible Ground, compared to the rest of the network. The Compressible / Collapsible Ground hazard rating is not directly comparable to hazard ratings derived for other hazard types. The map gives a separate hazard rating for Compressible and Collapsible, with the colour scale indicating the highest hazard rating of the two.

To undertake a qualitative assessment of the likelihood of either a collapse or subsidence, the following factors are relevant:

(A) The likely presence of Compressible / Collapsible Ground

- Refer to the Compressible / Collapsible Ground Hazard Rating map
- Geotechnical records or reports (see HAGDMS) of continuing long term settlement and repeat settlement mitigation on the SRN – usually caused by an inadequate understanding / mitigation at time of construction of initial and / or long-term settlement mechanisms

(B) Presence of any mitigating / exacerbating features

- Age of the SRN / loading asset – rate of compression decreases over time, unless an additional load is applied.
- Presence and effectiveness (condition) of any ground improvement measures implemented to mitigate Compressible / Collapsible Ground. Such measures may include but are not limited to: ground removal and replacement, pre-construction load surcharging, vertical drainage, compensation grouting or ground modification
- Presence of any mitigating / exacerbating features

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

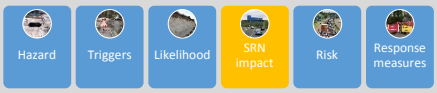
These may be considered by the type of triggering mechanism:

- Ground loading potentially beyond a stable limit
  - Construction, new structures, or temporary plant (primarily an issue with improvement schemes)
  - Traffic loading (volume) increases
- Water-related destabilisation (saturation):
  - Recent / forecast heavy or prolonged rainfall
  - 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)
  - Blocked / insufficient / absent drainage

An understanding of the likelihood of a Compressible / Collapsible Ground hazard event occurring may also be assessed from historical records and frequency of similar problems on the strategic road network and the surrounding area. Where HAGDMS contains report records* demonstrating that this hazard was assessed in accordance with current risk management procedures and standards it is reasonable to assume a lower likelihood of a hazard event. There is planned

* The Topic Search tool within HAGDMS facilitates a search across several of the system's databases for information related to a particular topic, for a chosen location. Topics are pre-defined by the System Administrator and currently cover a number of ground-related hazards and therefore the databases searched are focused on geotechnics rather than drainage.

research and development into the use of sensing techniques and other data to identify the presence of ground-related hazards, which could support the likelihood assessment described above.



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 event presents the highest safety consequence.
- The variable distribution and thickness of Compressible / Collapsible Ground – differential movements and settlement lead to greater damage to pavement, assets and structure compared to uniform settlement. Also see factor relating to SRN foundation level below.
- The size of the potential failure – a large failure presents a much higher safety risk to potentially many more users of the network than a small one would. Estimation of failure size requires local consideration and expert input.
- The location of the potential failure – ground movement directly beneath a main running lane presents both higher safety impact, and higher performance impact than beneath a hard shoulder or beyond.
- 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 shows early signs of a failure.
- The type of road – smart motorways being the most important in terms of performance, down to All Purpose Trunk Roads (APTR) being the least.
- The foundation level of SRN pavement / asset / feature – where support is provided from beneath any Compressible / Collapsible Ground through the using of piling, there is limited sensitivity to this hazard.
- 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 Compressible / Collapsible Ground 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 and service providers.

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.
- **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 Compressible / Collapsible Ground risk. Response plans should include:
    i. Engagement with Highways England technical specialists – named focal points (and responsibilities) should be clearly identified.
    ii. 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).
    iii. 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.
    iv. 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.

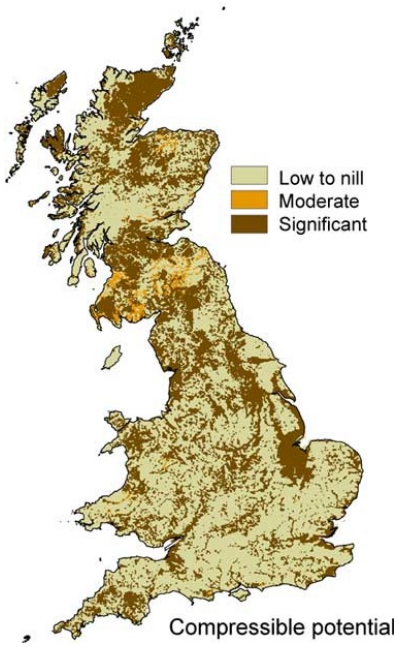
Part III An overview of Compressible / Collapsible Ground in England

1.0 What is Compressible / Collapsible Ground

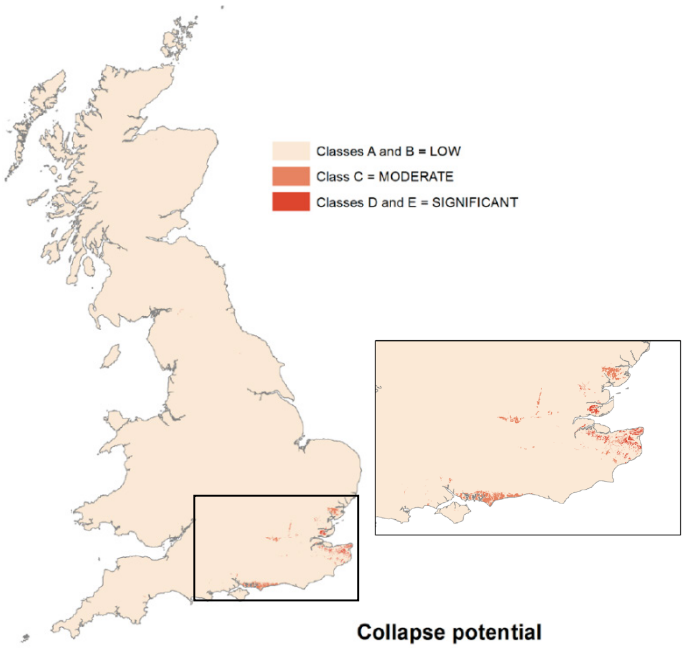
Subsidence on a road over compressible soil in Lincolnshire
© http://www.geograph.org.uk/photo/5322777

'Compressible ground' refers to mainly superficial deposits that are extremely soft (such as peat, alluvium and laminated clays) and susceptible to large progressive settlement when loaded or when the groundwater level changes. In these materials, they undergo initial rapid settlement (e.g. during or shortly after construction) followed by a slower rate of continued settlement that may extended for years after construction. Compressible deposits are found across the UK – see figure below (left).

'Collapsible ground', on the other hand, refers to metastable material that has a micro-structure of solid particles arranged at a relatively large spacing and which are bonded together by clay minerals (comparable to a dried sponge). Upon saturation it loses its strength as the water breaks the clay mineral bonds, and an applied load can then crush the internal structure, resulting in a sudden mass collapse. In the UK, collapsible ground is not widespread and the only susceptible rock type that has been identified is loessic silt (also described as brickearth), a wind-blown deposit. Being a transported sediment, brickearth may be present as an infill material within naturally occurring cavities – also see guidance note for Dissolution Features. Collapsible deposits are most likely to be encountered in parts of southern England (there might be other un-identified deposits) – see figure below (right).



Distribution and classification of compressible ground (Source: BGS)



Distribution and classification of collapsible ground (Source: BGS)

2.0 Compressible / Collapsible Ground and the Strategic Road Network

The hazard posed by Compressible / Collapsible Ground arises from the potential for the presence of compressible or collapsible grounds beneath the Highways England estate to either collapse suddenly and catastrophically or to cause subsidence/settlement. These hazards could be present due to:

- unidentified, and hence unmanaged, compressible / collapsible ground
- inadequate treatment methods (compared to current practice/guidance), which may correlate to the approximate date of treatment. In particular, secondary settlement (long-term settlement under constant load) may not have been understood / addressed at time of construction.
- the treatment 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
- changes made to the operation of the SRN or on land adjacent to the SRN causing changes in the magnitude and the distribution of the loads.

The hazard that the presence of these types of ground represents to the SRN is further significantly influenced by the groundwater level and the geology of the area.

Compressible ground is often readily identifiable on site, and, where present beneath the existing road network the risk, would most likely already be known following construction or subsequent maintenance work.

For collapsible deposits, as with all geotechnical assets, design and construction after the introduction of HD22 in 1992 would have been subject to a greater level of assurance and rigour, and collapsible deposits should have been identified and considered prior to construction.

3.0 Key references and further information

Compressible / Collapsible Ground Hazard Rating map, 2017, HAGDMS / HAGIS

HAGDMS Compressible / Collapsible Ground Hazard Rating data description, 2017

British Geological Survey, Collapsible Deposits, www.bgs.ac.uk, 2017

British Geological Survey, Compressible Ground, www.bgs.ac.uk, 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