

Work Package 1-194
Improved use of information in Geotechnics

Final Report Part 2 - Detailed findings

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1. Introduction

Task 1-194 'Improved use of information in geotechnics', was awarded by Highways England to Arup AECOM under the SPaTS research framework.

This report describes the findings of study undertaken for this task, including recommendations.

This report is presented in two parts:

- ‘Part 1 - Overview and Recommendations’ (separate document) provides background, a summary of the task, a summary of the findings detailed in Part 2 and a list of recommendations for work to address the findings.
- ‘Part 2 – Detailed Findings’ (this document) provides a detailed account of the assessment and analysis, and presents the findings of the study, including recommendations at the end of each section, presented in context.

Part 1 is intended to be a standalone document, which should be read in conjunction with Part 2 where further detail is required.

Work on this project commenced in January 2017 and reported in April 2018.

1.1. Purpose and scope of study

The task considered the use of geotechnical data and information throughout the asset lifecycle, including:

- site investigation
- monitoring
- inspections
- decision support systems
- design
- construction (including repairs, renewals and improvements)
- inspections
- maintenance
- disposal

The aim of the task was to investigate and identify data and information requirements that have been established from other research tasks, day-to-day activities and external initiatives. Also it was to look at the future regarding the likely technology landscape that will exist, to enable Highways England to make the best use of information and realise the potential benefits e.g. improved data management and data visualisation.

2. Approach

This review was undertaken through a number of desktop reviews complemented by significant stakeholder inputs, as summarised below. Detailed findings and recommendations are presented in Sections 3 to 7 of this report. A summary of the findings and analysis and prioritisation of the recommendations please refer to Part 1 of this report.

2.1. Desktop reviews

A series of desktop reviews was carried out including:

- baseline review of current practice, including literature review of key Highways England documents (Sections 3 & 4)
- review of Highways England internal initiatives (Section 5)
- review of external initiatives (Section 6)
- technology review (Section 7)

A limited literature search was carried out with detailed reviews only undertaken where directly relevant to the study. The knowledge gained from publications, articles and websites seen during this study has also been useful as it is indicative of past, current and potential future trends in the industry.

- Other Highways England groups and studies were consulted, with meetings held with these groups 24 January and 12 July 2017.
- Handover of Geotechnical information from Major projects back to Highways England
- Asset Data Management Manual
- Highways England Asset Improvement programme
- IAN 182/184, Employers Information Requirements (EIR)
- Highways England BIM initiatives

A bibliography of key sources consulted in this study is presented at the end of this report.

The above literature review has fed into the baseline review of practice. The core team first undertook analysis of current ways of working and current information flows on Highways England projects involving geotechnical activities. As well as providing early identification of the key issues to consider, this also helped to optimise the structure for subsequent consultations.

A review of relevant tasks and activities that have/are being carried out by Highways England was undertaken. The findings from task reports were reviewed and any outstanding, relevant recommendations collated and brought forward as recommendations from this task. Information on external initiatives was largely obtained from research of online and published sources, see Section 6 of this report. In addition:

- The core team members are active participants in the AGS Data Format Working Group.

- Information on Uniclass 2015 was presented to the project team by NBS¹ at a meeting on 12 July 2017.
- Information on buildingSMART² and Industry Foundation Classes³ was discussed during a telephone call with Nick Nisbet (vice chair of buildingSMART UK Chapter) with further information obtained from Arup's attendance at the buildingSMART Summit held in November-December 2017.
- A presentation on 'BIM⁴ for the subsurface' was given at an AGS Data Format Working Group meeting attended by the core team.

Lastly, a technology review looked at recent advances in smarter ways of capturing, storing, analysing and presenting data that could be adopted by Highways England and their supply chain.

2.2. Stakeholder activities

This study has been led by a core team from Arup AECOM, with feedback and opinion from a variety of stakeholders. This included designers and contractors from the supply chain as well as key stakeholders in Highways England. Information was gathered from a combination of meetings, interviews, informal discussions and exchange of correspondence.

Feedback and opinion has been sought from a variety of stakeholders, including:

- Highways England project sponsor David Patterson: initial meeting and a number of subsequent discussions and exchanges of information
- Interviews with Arup staff involved in Highways England projects
- Meetings, discussions and correspondence with lead participants in other Highways England groups including representatives from site investigation contractors, engineering consultants on the Smart Motorways Projects and Highways England Geotechnical Advisors.
- Informal discussions with colleagues and peers, both internally and at external meetings or events.

Other Highways England task groups were consulted with the findings from other studies incorporated where relevant.

On two occasions presentations relating to this study were made at the Geotechnical Asset Owners Forum (GAOF), which is attended by the discipline leads of other asset owners such as Network Rail. A presentation was also given at the 'Geotechnical data conference 2017', organised by the Association of Geotechnical and Geoenvironmental Specialists (AGS).

¹ [NBS-uniclass-2015](#)

² www.buildingsmart.org

³ [ifc-introduction](#)

⁴ Building Information Modelling

3. Baseline review of general practice

3.1. Overview of geotechnical information in Highways England

The scope of the baseline study into geotechnical information in Highways England has primarily considered the information used throughout the asset lifecycle. It includes both data (e.g. AGS format data and geotechnical asset data) and information (e.g. site investigation and research reports) and also looks at the processes and human interaction with the data (e.g. competencies).

3.2. Overview of information transfer formats and processes

This section introduces some of the most common and relevant formats and methodologies for information storage and transfer within Highways England, as well as some general concepts and definitions that are common to the discussion on baseline that follows.

Much documentation, including this report, is still primarily held or exchanged as PDF (Portable Document Format). This universally adopted format for document presentation and exchange was originally proprietary, invented by Adobe, but it is now it is published as an open standard: ISO 32000-1:2008 (International Organization for Standardization [ISO], 2008). The use of PDF is further discussed later in this report. (Section 7.4)

Within the geotechnical community in the UK, the AGS Data Transfer Format (Association of Geotechnical and Geoenvironmental Specialists [AGS] 2017), hereafter described as the 'AGS format,' is well known and commonly used for exchange of ground investigation and (less commonly) monitoring data. It was created and is maintained by the Association of Geotechnical and Geoenvironmental Specialists (AGS). The work of the AGS Data Format Working Group is discussed in Section 6.4.2. Use of the format within Highways England is discussed in the relevant sections of the baseline review that follow, with further detailed review and discussion provided in Section 4.2.

Drawing and model data is currently generally exchanged using proprietary software file formats, such as DWG files from Autodesk AutoCAD or DGN files from Bentley Microstation. Both AutoCAD and Microstation can produce 2D or 3D model files.

IAN 184⁵ (2016) Section 3.2 states that *"as there is no widely used open format for CAD the commonly used proprietary dwg, dgn and rvt, and the open BuildingSmart ifc formats are acceptable."*

The Highways England geotechnical asset data management system (HAGDMS) is a web-enabled, map-based database containing information relating to the geotechnical asset infrastructure. HAGDMS is discussed in detail later in this report (Section 5.2).

Project information is sometimes managed using a Common Data Environment (CDE), defined as a single source of information for any given project, used to collect, manage and disseminate all relevant approved project documents for multi-

⁵ INTERIM ADVICE NOTE 184/16 Highways England Data & CAD Standard Instructions on naming conventions, file types and data structures for the delivery and transfer of CAD / BIM files to Highways England and its supply chain.

disciplinary teams in a managed process. A CDE may use a project server, an extranet, a file-based retrieval system or other suitable toolset.

Guidance specific to geotechnical information is provided in BS8574:2014 Code of Practice for the management of geotechnical data for ground engineering projects (British Standards Institution [BSI], 2014), which describes how to set up a formal system for the management of geotechnical data. It is intended for use over the whole life cycle of geotechnical assets and is relevant to all types of practitioner, including clients. This topic is discussed in detail later in this report (Section 4.1)

3.3. Findings of baseline review

3.3.1. General

Access to Highways England standards is reported to be good, as these are all freely available online. Access to knowledge, e.g. discovery of published work on a particular subject, can be more difficult. This relies on the skill and knowledge of the individuals undertaking the search, and the resources available to them given that many online repositories of published information charges subscription fees.

Based on interviews, there appears to be a low level of awareness of BS8574 (management of geotechnical data) within the supply chain. Some ground investigation companies have set up BS8574 compliant systems but few consultants or other supply chain companies have done so.

The use of a Common Data Environment is reasonably common on major Highways England projects. Adoption is driven by the supply chain, not Highways England, with collaboration by parties within a joint venture arrangements cited as a common reason. A variety of systems are being used, e.g. Bentley Projectwise on A303 Stonehenge, Business collaborator on A14 Cambridge to Huntingdon. One observation made is that some Common Data Environments do not integrate well with Geographical Information systems resulting in information that is difficult to access and/or visualise.

In terms of asset management there is no single CDE in terms of a “system”. However the Asset Data Management Manual, which forms part of Highways England’s Asset Management System, seeks to specify the virtual CDE for asset information. At the time of writing only inventory information is specified.

Discussion and recommendations

Further discussion and recommendation relating to Highways England knowledge management systems and use of BS8574 are provided later in this report.

The use of CDE on projects is a key requirements of BIM and this should be encouraged. However, this is a cross-discipline issue related to project delivery that should be led by other parts of Highways England, most likely the Asset Information Group (AIG). The use of a CDE within the geotechnical phase of a project can be problematic because of the timing of the work (i.e. prior to a Project-level CDE being implemented) or because the scope of the project doesn’t warrant the use of a CDE.

3.3.2. Desk study (PSSR)

Highways England’s approach to risk management is established by HD22 (Highways Agency, 2008), which requires a desk study or Preliminary Sources Study Report (PSSR) in Key Stage 2 of the Geotechnical certification procedure.

HAGDMS is seen to be a good resource for acquiring information for the desk study, speeding up the process and exposing information that may otherwise have been overlooked. However, the information held within HAGDMS could be improved, as could access to it. Feedback from stakeholders provided the following observations:

- Obtaining access to HAGDMS could be easier for users further along the supply chain.
- It is not easy to use for occasional user.
- Asset details and performance information not always found.
- Does not include information on foundations or piling, which are of interest to geotechnical engineers.
- AGS data, whether found via HAGDMS or from other sources, is considered to be a high value resource when available. However, the quality of older 'historical' AGS data can be variable, leading to a need to carry out some re-processing of the data. Common problems include:
 - Inconsistent use of soil material codes⁶ (or sometimes not used at all)
 - Inconsistent use of other codes, e.g. hole or sample types
 - Missing co-ordinates or levels

Some of these comments relate to the data held and some to training and familiarisation.

The desk study will identify and report on any ground investigation data available that is relevant to the project, generally from previous Highways England projects or from British Geological Survey archives. This data will normally be taken into account in later interpretation for design. However, this requires judgements to be made on the quality and reliability of this data. Sometimes this can be difficult to assess if the original reports provide no information on what verification regime was in place at the time, e.g. was there independent site supervision, and has the report been independently reviewed. The reliability of old AGS files must also be considered. There is no defined method for assessing quality and reliability of data.

Desk study reports, interpretative reports, design report and, especially, Geotechnical Feedback Reports from relevant nearby projects can provide extremely valuable input to the desk study. These convey knowledge, i.e. lessons learned, as well as data.

Geographical Information System (GIS) is commonly used for compiling, analysing and presenting desk study information, especially on larger projects. Key observations with respect to use of GIS include:

- It is generally not easy to apply good data management principles when working within GIS and it requires skill and discipline.
- Referencing live data sets within GIS is possible but this not compatible with traditional version control methods.

⁶ Soil material codes may be geotechnical soil types and should be specified at the start of the investigation.

- Transfer or exchange of GIS data sets is rare.

Desk study information is generally compiled in a single report, currently known as the Preliminary Sources Study Report (PSSR). HD22 includes prescriptive requirements for a PSSR. Whilst PSSR/desk study reports are generally seen to be valuable sources of information, the following feedback has been obtained:

- Reports produced now differ little from those produced 20-30 years ago (other than being PDF instead of hard copy). The documents are often very large, resulting in slow file download and predominantly text-based. They often have large amounts of “boiler plate” text that do not add to the message being conveyed.
- Reports not convenient to use as reference document with indexing often poor or non-existent.
- Treatment of source data is inconsistent. Referencing to sources not included in the report is often poor. Appending source information to the document improves traceability but edits and annotations from the document authors can cause confusion. This approach also leads to large and cumbersome documents, especially when scanned images are incorporated.
- Key messages about risk can get lost.
- Reports not updated when more/new information arrives.

Regarding the last point, it is acknowledged that the process outlined in HD22 does not allow the PSSR to be revised after the ground investigation but it goes on to say that “Confirmation or amplification of problems found in the PSSR” is to be included in the GIR.

Discussion and recommendations

The desk study process is regarded as being of high value and it appears to be implemented reasonably well, with HAGDMS proving useful and GIS being used to good effect by some suppliers. However, it is felt that improvements can still be made, particularly in relation to the AGS data acquired from legacy ground investigations and the presentation and subsequent exchange of the desks study information collected.

The presentation of desk study information, including electronic information, has been covered in previous Highways England studies, reported 2008 and 2010. These studies are discussed in detail later in this report. Several of the issues were considered at the time, or are still relevant.

Assessment of the reliability of historical ground investigation data is a matter that is relevant to ground investigation reporting and design as well as desk study, which is why critical appraisal by experienced geotechnical engineers is necessary.

It is recommended that Highways England promotes the creation of a simple system for assessing the quality of ground investigation data, primarily based on the verification regime adopted at the time. This will provide a consistent basis for assessing reliability of legacy data, and this could be presented in the PSSR. Future users of graded 'new' data will immediately be able to take a view on its reliability.

Regarding the presentation of the PSSR and desk study information, it is recommended that consideration be given to the following:

- Ensure that source data for the PSSR is made available, preferably via the project CDE.⁷
- PSSR report format developed to give more emphasis to map-based presentation (web enabled), perhaps accompanied by a more concise text based report and risk register.
- PSSR to be maintained as a live document⁸ that evolves with the project. This could also be linked to development of web enabled GIS and alternative report formats. This will ensure that desk study type information discovered after PSSR issue is shared in a more visible way. Version control systems should be used to provide traceability for data.

It is recognised that some of the above, chiefly the recommendation for the PSSR to remain a live document, would be difficult to achieve without appropriate use of technology and modification of current processes. There also needs to be consideration of the boundary between the PSSR and the Geotechnical Feedback Report. The latter could be achieved through the use of metadata to record the source of information.

3.3.3. Ground investigation

A commonly held view is that the ground investigation process proceeds much more slowly than it should. This is important given that the ground investigation is the primary source of geotechnical information for a project. It is not uncommon for the final report to arrive late in the design process, and commonly later than originally programmed. The main problem relevant to this study is the post fieldwork process where the following observations have been made:

- Information flows during laboratory test scheduling phase slow and inefficient, generally using spreadsheets, not AGS data.
- Preliminary AGS data sometimes provided with logs, but it commonly lacks co-ordinates and/or levels⁹, and soil material codes.
- Draft and final reports are generally issued as single 'documents' towards the end of the process, even for investigations where the fieldwork itself was spread over several months.
- Formal check/review by investigation supervisor, most commonly done on the full draft report, can be a source of further delay.
- The Bill of Quantities is structured so that the ground investigation contractor receives most of their payment even if the reporting is late and/or defective.

These problems are not unique to highways projects, but one respondent did note that on some occasions the procurement routes for ground investigation on

⁷ Subject to copyright restrictions

⁸ The PSSR should be reported as snapshots at key stages.

⁹ The co-ordinates and levels may be approximate at preliminary stage, but should be measure to the correct precision as soon as possible.

Highways England projects is often convoluted and this can impact on the quality of ground investigation and data delivery.

Another issue arising from Highways England procurement practice is the handover of a project from one consultant to another at various times. This can occur during or after ground investigation for example when designers or managing agents change. It was noted on the A303 Stonehenge Project that useful knowledge and observations from the Investigation Supervisor could potentially be lost, as they would not necessarily get included in the Geotechnical Interpretive Report (GIR), which is completed later. On the A303 project it has been agreed that the gap should be filled by a close-out report from the Investigation Supervisor, despite this not being required by HD22.

During the fieldwork, the use of digital field data capture is increasing with more contractor's investigation in tablet computer and the relevant software.

Information flows during the ground investigation are still most commonly dominated by email with the use of a Common Data Environment (CDE) for sharing data rare.

The format of ground investigation factual reports is still generally the same as it was 20 or 30 years ago, except that delivery as a PDF is now routine (as required by Highways England). The report is generally delivered as a single file, or often split into smaller volumes to aid downloading.

AGS data is routinely provided on Highways England projects. The general view is that the quality of AGS data remains mixed although it has certainly improved over the years. Use of latest AGS4 format took several years to become embedded but it now appears to be routine.

Some of the inconsistencies seen between AGS files are the result of inconsistent or incomplete specifications. The AGS documentation does not a full specification and the Highways England Specification for ground investigation (Highways Agency, 1997) provides limited further definition, with the full specification left to the specifier. The most obvious example of inconsistency is soil material codes. However, some problems are caused by inconsistent referencing of exploratory holes, tests and samples.

Checking of AGS data remains a challenge. Proprietary checkers only check compliance with format rules, e.g. the completeness check – does the data include everything in the factual report (except for identified exclusions). The Highways England Specification for ground investigation clause 12.4.7.4 requires the “Digital Data Report” to identify where “data are included as a paper record but are not included in digital form”, but no examples of this being applied have been seen. Accuracy of the data, i.e. is it the same as the paper copy, relies upon the data and factual report being produced from the same version of the same database.

Missing or incomplete groundwater monitoring records is an especially common failing within both factual reports and AGS data. This is likely caused by the data being collected after the main fieldwork period, and sometimes after reporting.

The traditional Geotechnical Interpretive Report (GIR) is of critical importance. As well as being a key project reference document, it is also usually the first place that people look to find geotechnical information about a site. The intelligence provided by a good GIR is extremely valuable, both within and beyond the project it is intended for. However, many have also commented that interpretive reports are

often very large, wordy, with poor data plotting, sometimes making it difficult to find the desired information quickly.

HD22 requires a GIR, as defined by in BS EN 1997-2 (Eurocode 7 (EC7) (BSI, 2010) to be produced. It is a common misconception that the GIR is simply made up of the PSSR, factual report and a traditional interpretative report, but this is not strictly speaking the case. A traditional interpretative report normally includes parameters for design, which for an EC7 design would be EC7 characteristic values. However, EC7 recommends that the GIR includes an evaluation of the data, but goes on to recommend that characteristic values, i.e. design lines, be presented in a Geotechnical Design Report (GDR), thus there is confusion between GIRs and GDRs. Unfortunately, the current version of HD22 confuses matters further by requiring GIRs to include a ground model and parameters, but it is unclear what parameters it requires. A number of recent GIRs have been reviewed and it has been found that the authors are inconsistent in their approach, with some reporting characteristic values in the GIR, and some not.

HD22 is prescriptive in the format (headings) of a GIR. Some have reported that they find this restrictive, although many appreciate the guidance on content.

Interpretative reporting often includes some modelling of geological surfaces. For the purposes on this study, this is discussed in the following 'design' section.

Discussion and recommendations

The main themes arising relate to slow ground investigation process and the reporting, including delivery of AGS data. It is considered that both the ground investigation process and reporting are long overdue an overhaul, given that on many projects they are little changed from what was seen 20 to 30 40 years ago. This is an industry issue but Highways England is in a good position to take a lead on this, and Highways England should benefit from reduced costs and faster delivery regardless of whether the approach is adopted elsewhere. This is especially relevant for Smart Motorway schemes, where just-in-time delivery (i.e. delivered at a time appropriate for the final design to be adopted) is sometimes the only practical option.

It is suggested that such an overhaul should have the following objectives:

- Move away from the historical approach of delivering one big report at the end of a ground investigation, with nothing officially finalised before then
- Greater prominence should be given to data over the (text based) report
- Better planning for the delivery of data, with important concepts such as referencing systems clearly established at commencement
- Move towards routine electronic capture of data in the field
- Streamline the post fieldwork process, i.e. laboratory testing scheduling, testing, review of output data, in order to achieve faster delivery of final data
- Reports should be more user focused in their presentation, and ideally also easier to produce
- Generally improve efficiency by taking advantage of the digital technologies that are now routinely being used in other parts of the industry

The following specific recommendations for Highways England aim to address the above. For each of these, the recommendation is for Highways England to promote the change. How this is best achieved requires further follow on study, but it is likely to be through a mix of changes to specifications and/or guidance documents, implementation of pilot projects and encouraging innovation from suppliers by sponsoring awards.

- Suppliers to provide formal plans for data management on ground investigation projects, to comply with BS8574 and PAS 1192-2 (BSI, 2013), i.e. equivalent to a BIM Execution Plan.
- Use of a Common Data Environment (CDE) at ground investigation stage for sharing of data and collaboration. This may require establishment of a CDE specific to the ground investigation if none is already in place. In fact, this may be a better solution as the CDE could be optimized for ground investigation and it may allow contractors to offer their own solutions, e.g. FugroOnline.
- Develop the use of AGS format for issue of hole scheduling information to ground investigation contractor. The data communicated could relate to specific health and safety information about the exploratory hole, e.g. permit to dig, services; or particular sampling, or in-situ testing instructions. This will require revision of the AGS format as this is not included at present, albeit it can be done now with some imagination. This will promote the importance of structured data exchange and should lead to consistent hole referencing.
- Routine use of field data capture for ground investigation. This includes use of mobile technologies as well as developing electronic capture of field test data to replace current manual methods.
- Exchange of laboratory test schedule information as AGS data (format already exists).
- AGS data to become the primary deliverable from a ground investigation, with the report a secondary view of that data. Requires further development of AGS format, as discussed later in this report.
- New format for ground investigation factual report that is more user focused and easier to deliver. Ties in with the recommendation for AGS data as the primary deliverable.
- Early/incremental issue of final ground investigation data/report. On long duration ground investigations, the data/report should be finalised and delivered as it become available, instead of waiting until completion of the whole of the ground investigation. This takes on board current best practice where draft data is issued incrementally, but goes beyond this to require finalisation of the data. This would be facilitated by implementation of the recommendation for new factual report format and AGS as primary deliverable. However, it is recognised that this approach may not be appropriate for all ground investigation, e.g. those where the soil classification needs to be developed during the ground investigation.

Recommendations relating to ground investigation procurement, which could impact on ground investigation process, are discussed later in this report (Section 3.3.5).

In addition, the following specific recommendations address particular issues arising from the review:

- Review Highways England use of abbreviation codes in AGS format data, including geology codes and possibly coding for lithology. Aim for a consistent specification that is fully aligned with AGS and, preferably, also aligned with BGS and other asset owners.
- Improve Highways England specification requirements for AGS data. Incorporate findings from the abbreviations/soil material codes review and address concerns relating to inconsistencies on referencing. Consider incorporating existing AGS guidance and/or create new guidance. Consistent specification helps everyone in the supply chain, especially ground investigation contractors.
- Report on site observations by ground investigation supervisor to be required when interpretation is to be delayed, or done by another supplier. This will ensure key observations and knowledge gained from site are not lost in cases where GIR does not follow directly on.
- Clarify what design parameters should be reported in GIRs and GDRs respectively. HD22 is currently unclear and EC7 is difficult to interpret. This should lead to more consistent reporting.

Further specific recommendations relating to AGS data are discussed in more detail later in this report (Section 4.2).

3.3.4. Design/Ground Modelling

An important aspect of geotechnical design is modelling of the geological profile, including the ground surface and groundwater.

The most common output is a 3D surface representing top or bottom of strata that can be viewed and usually manipulated in CAD or GIS software. These surfaces often later get incorporated on cross section drawings. They are also often used within CAD or modelling software for generation of earthworks volumes or identification of founding strata.

Designers are using a variety of methods to create models. It is likely that many only utilise the exploratory hole data without review of the surfaces created. However, there are examples of surfaces created using a more rigorous approach, such as using systems which allow a geologist/engineer to review the surface initially computed from the data, allowing manual modification to account for faults or other geological features.

For linear infrastructure it is often the case that data points are only available along the alignment, or very close to it, making it difficult to compute a 3D surface. In such cases the model may be simply based on extrusion perpendicular to the data points along the alignment.

Transfer of ground models between organisations is not commonplace. There are no established protocols although it would not be difficult for two parties to come to an agreement on a mutually acceptable format for exchange if required. Examples would be a proprietary CAD based file formats or a LandXML surface (see section 6.3).

Whilst models are often created and sometimes shared, information on what the surface represents, its methods of creation and guidance on uncertainty, are not being made available.

The other aspect of design relevant to this study is the trend towards increasing use of automation in design. The almost universal view is that the use of automation in design processes will increase greatly in the coming years, possibly significantly impacting on the day to day role of the engineer. Current methods of working generally involve manually moving or processing data between analysis and/or modelling tools. Most current effort in the field of automation is aimed at these interfaces. Methods vary, but they usually include one or more of the following:

- Control via scripts written in .NET, Python, R, Dynamo, Grasshopper, C# or the like.
- Scripts directly access software via the Application Programming Interface (API) where this is available for that software.
- Use of FME (Feature Manipulation Engine) software to transform data.

Typically geotechnical engineers have used BASIC, Visual Basic, then, Visual Basic for Applications (VBA) (code that runs within MSAccess or MSExcel) to automate tasks when processing data. However, these languages are now legacy software¹⁰ and do not support modern frameworks and data structures. As a result there appears to be a trend away from this towards scripting using the tools/languages noted above (see Section 6.5).

Discussion and recommendations

The key themes here are ground modelling and automation.

It is recommended that Highways England supports or leads the establishment of a protocol for exchange of ground model data, with a focus on the metadata describing what the surface represents and how it was created. This will facilitate a consistent approach across the supply chain and it should also reduce the risk of inappropriate use of data. Digital exchange of interpretative data, e.g. design parameters, did not arise as a significant issue from the study, but this may be because few have seriously considered it.

It is recommended that Highways England works with AGS on their creation of a data transfer format for interpretative ground investigation data (see also Section 6.4.2). There is a clear link between this and exchange of ground models, i.e. if models are being shared, then it would be normal to expect parameters to be shared too. Furthermore, a structured format could facilitate cross project analysis of archive data, with benefits for future design and asset management.

The development of automation in design will continue to be driven by designers in conjunction with IT specialists, and it is likely that the technologies used will evolve over time. It is recommended that Highways England be supportive of this, but no specific actions are suggested at the time of reporting. However, by implementing this report's recommendations relating to provision and use of structured data

¹⁰ VBA is being replaced with Visual Studio Tools for Office (VSTO), however this requires additional software (Visual Studio), which removes the ease of access to the non IT professional.

Highway England will support automation given that structured data is a critical element in most automation projects.

3.3.5. Procurement

With regards to the wider construction industry, recent feedback from piling and geotechnical contractors indicates that they often do not receive AGS format data at tender stage. Some struggle to obtain the full ground investigation reports, let alone the AGS format data. Highways England projects have not been studied in detail in this respect, but based on discussions it appears that this is also often the case on Highways England projects too.

This problem also extends into the construction phase. Further discussion of the causes, and possible solutions, is given in the Construction section below.

3.3.6. Construction

As noted in the Procurement section above, many contractors report that they do not receive AGS format data. This is based on feedback from the Federation of Piling Specialists (FPS) and comments by many industry professionals. This is a whole industry problem, but some contractors reported that this is also often the case on Highways England projects.

A number of possible reasons for the problem have been suggested, including:

- Late delivery of AGS format data
- Concerns over data ownership and liabilities
- Document management systems not set up to handle data file
- AGS format data not attached or linked to the factual report
- Perception that AGS format data is only of value to the original designer
- Non geotechnical professionals not understand what it is, or failing to appreciate its value

There are some positive exceptions. For example, it has been reported that the contractor on the current A14 Cambridge to Huntingdon Improvement project has commented that the data made available is the best they have ever seen.

The Smart Motorway Programme is also using existing AGS format data to supplement data obtained during site investigation. The integrated nature of the design and contract process enables the AGS format data to be shared easily.

Regarding the collection of site data, there is a trend towards increasing use of field capture of data using mobile technologies or instrumentation. However, there is a perception that the industry is not taking full advantage of this.

For earthworks records, e.g. compaction, full records are not normally retained. There could be opportunities to collect data that may be useful for later analysis of asset performance, which in turn could feed back to better evidence based design. An example is the data that could be made available from Compaction Continuous Recording (CCR).

On some projects, including the A14 projects, there is a lot of use of tablets on site, but the outputs being produced are PDF version of traditional records. The data within these records is clearly created in a structured form, to create the record, but the data itself is not being made available (see Section 7.4).

Monitoring data, which may be associated with earthworks operations, is often obtained during construction. However, data is most commonly exchanged using spreadsheets, with no common data structure. Most monitoring data is covered by the AGS format but this appears to be rarely used for monitoring data.

There are currently no industry standards for the transfer of construction data, although there are some current initiatives in this field, as discussed later in this report (see Section 6.2).

HD22 requires Geotechnical Feedback Reports to be produced at the end of construction, and this appears to be generally complied with. These reports are considered by many to be valuable sources of knowledge, providing insight that may not be apparent from interpretation of data.

Discussion and recommendations

It is recommended that Highways England further investigates the reasons for AGS format data not reaching contractors. Based on the findings, Highways England should then develop a system to ensure that AGS format data, and other key data such as PSSR source data, is made available and easily discoverable during procurement, and at construction stage¹¹.

Digitisation of construction data should provide obvious benefits including:

- Opportunity to exchange data digitally on site, which in turn should facilitate improved technology driven data review methodologies.
- Future asset performance data could be correlated against construction data, providing feedback to improve future design.

Analysis of data relies on the availability of structured data. Therefore there needs to be a focus on how the data should be structured. AGS data for ground investigation provides a good example. AGS is already starting to develop transfer formats for some construction data, as discussed later in this report, therefore it would make sense for Highways England to participate in this work. The following are specific recommendations:

- Collect data from Compaction Continuous Recording (CCR) on earthworks construction where it is used.
- Extend the AGS data format for use in earthworks compliance testing and other geotechnical construction activities.
- Support current AGS work on format for piling data (currently part of Highways England structures remit, but of interest to geotechnical engineers)
- Support current AGS work on format for grouting data. Identify other processes that may benefit from AGS format data.
- Review suitability of current AGS format data for monitoring data and, if necessary, recommend improvements to AGS.
- Following on from the above review, promote the use of AGS data format for exchange of construction monitoring data.

¹¹ Subject to copyright restrictions

Geotechnical Feedback Reports (GFR) are a valuable asset, and it is interesting to see that the recently released draft of the proposed revision to EC7 will require GFRs to be produced for all construction projects. GFRs often contain recommendations and insight that deserve a wider audience so that others can benefit.

Therefore it is recommended that large and/or complex projects also be required to produce publications on relevant topics for external dissemination.

3.3.7. Asset management (operation and maintenance)

Geotechnical asset data is managed using Highways England's geotechnical asset information management system (HAGDMS). The system has successfully maintained a primary source of asset information including a records repository. However the construction information held in HAGDMS is very limited and the method of transferring as-built information into HAGDMS is very manual.

There are a number of asset management related tasks either ongoing or recently completed that are discussed later in this report, e.g. reviews of HAGDMS, SGM Task (594) and Geotechnical Data Handback Task (1-510), which include a number of recommendations.

Key observations that have arisen from the review are:

- There seems to be little direct linkage from design through to asset management, i.e. future assets are not explicitly identified at design or construction stage, with the asset breakdown for asset management only considered at handover. This is contrary to the vision for BIM which envisages seamless transfer of data through design, construction and on to asset management.
- The Specification for Highway Works (SHW) fill type for embankments and other construction materials is not carried through to HAGDMS. This construction information would be easy to obtain and useful in the long-term.
- Monitoring (from instrumentation) carried out during asset management is generally not made available in AGS data format.

The following specific recommendations address the above.

- Identify (future) assets at design and construction stage. Consider concepts similar to **COBie** (Construction Operations Building Information Exchange) data drops. If Highways England asset management needs are considered from an early stage this should make the eventual data drop into HAGDMS more straightforward. It could also allow 'under construction' assets to be incorporated in HAGDMS if desired.
- Asset monitoring data (from instrumentation) to be made available in AGS data format. This will make it easier to back-analyse large data sets data to benefit future design, construction and/or asset management.
- Consider adding SHW fill class to HAGDMS for new construction. This will improve linkage through from design, and it provides more opportunities for analysis of data.

4. Detailed review of key issues raised in baseline review

The key issues encountered during the baseline review centred on the following topics:

- Use, or lack of use of BS8574
- Application of the AGS Data format
- Access to information in Highways England and
- Procurement of ground investigation

These are covered in more detail in the following sections.

4.1. Use of BS8574

BS8574 "Code of practice for the management of geotechnical data for ground engineering projects" was published in March 2014. It was prepared largely by members of the AGS Data Format Working Group to help embed best practice in the field of geotechnical data management. It intended to plug the gap between quality systems (ISO9001), which focus on the management of information and BIM, which also looks at data and information, but of the built environment, not the existing environment.

BS8574 provides a framework for the creation and maintenance of a data management system, using the same principles of other management systems such as quality and health and safety. It requires the system to have ownership and audit and continual improvement. The systems can be implemented at both a project and organisational level.

Highways England makes reference to BS8574 in IAN 184:

"5.2. Geotechnical Survey Survey data for boreholes and trial pits shall be presented in AGS (Association of Geotechnical and Geoenvironmental Specialists) format in accordance with HD22/08.

*A strategy for unique borehole numbering shall be implemented and maintained, in accordance with **BS8574**."*

However this reference is very limited in scope, relating only to the requirement for the unique referencing of exploratory holes.

Reference to BS8574 is also included in the Employer's Information Requirements for schemes, but the requirement to demonstrate compliance is not explicit.

The HS2 project has implemented the requirement for suppliers to have a data management system and plan in accordance with the principles set out in BS8574. This has helped with the successful delivery of the ground investigation information on that project by ensuring that roles and responsibilities, and information management systems were documented and communicated.

The use of BS8574 throughout the supply chain and Highways England will be an important step to manage the flow of data. It will provide the governance required to ensure that data is provided in a timely manner to the required quality.

It is recommended that Highways England set up a data management system in accordance with BS8574 and specify that its suppliers also set up either project-level or organisational-level data management systems that can interface with Highways England's project reporting requirements (i.e. the file formats are compatible with Highways England's current and future information systems). The Highways England data management system should reference existing requirements and processes where possible, it should not look to replace embedded procedures.

This recommendation is compatible with the specific recommendation made earlier (for suppliers to provide formal plans for data management on ground investigation projects, to comply with BS8574 and PAS 1192-2, i.e. equivalent to a BIM Execution Plan).

4.2. AGS data transfer format

4.2.1. Overview

Within the geotechnical community in the UK, the AGS Data Transfer Format is well known and commonly used for exchange of ground investigation and (less commonly) monitoring data. It was created by and is maintained by the Association of Geotechnical and Geoenvironmental Specialists (AGS), specifically its Data Format Working Group. The work of this group is discussed in Section 6.4.2.

AGS format documentation was first published in 1992 but it has evolved over the years to keep pace with the requirements of the industry. The current major version (Version 4) was released in 2011 and reflects the requirements of Eurocode 7 and associated ISO standards. The current revision is defined in the AGS publication: Electronic Transfer of Geotechnical and Geoenvironmental Data, AGS4, Edition 4.0.4 - February 2017 (AGS, 2017) which is available at www.ags.org.uk.

The AGS format is a simple text based file format defined by a set of rules and a data dictionary.

The typical use of the AGS data format is provision of data with the final "factual" report, either for use in the design process, and/or for long-term storage.

Use of the AGS format is specified in Highways England's standards (HD22/08, and IAN184):

“5.2. Geotechnical Survey data for boreholes and trial pits shall be presented in AGS (Association of Geotechnical and Geoenvironmental Specialists) format in accordance with HD22/08.

File format shall be AGS version 3.1 or later.”

The AGS format is well established and well supported by the industry. There was a move, some time ago, to align the format with the DIGGS initiative (Data Interchange for Geotechnical and Geoenvironmental Specialists). However, as discussed in the later section on DIGGS (Section 6.4.3), the DIGGS project lost momentum. Whilst a DIGGS schema does now exist, it does not appear to be well supported by software and it currently offers no advantage over AGS to users in the UK.

4.2.2. AGS in HAGDMS

Highways England's geotechnical asset information management system (HAGDMS) is the central, long-term storage repository for the AGS data format files produced during site investigations. The ability to upload the data rests with the managing agent, or scheme designer (the "Engineer").

Analysis of the report types and associated AGS data format files shows that there is quite a significant gap between the reports that should have AGS data and those that actually have. The population of AGS data format files is reported in a draft monthly geotechnical asset information report (see below).

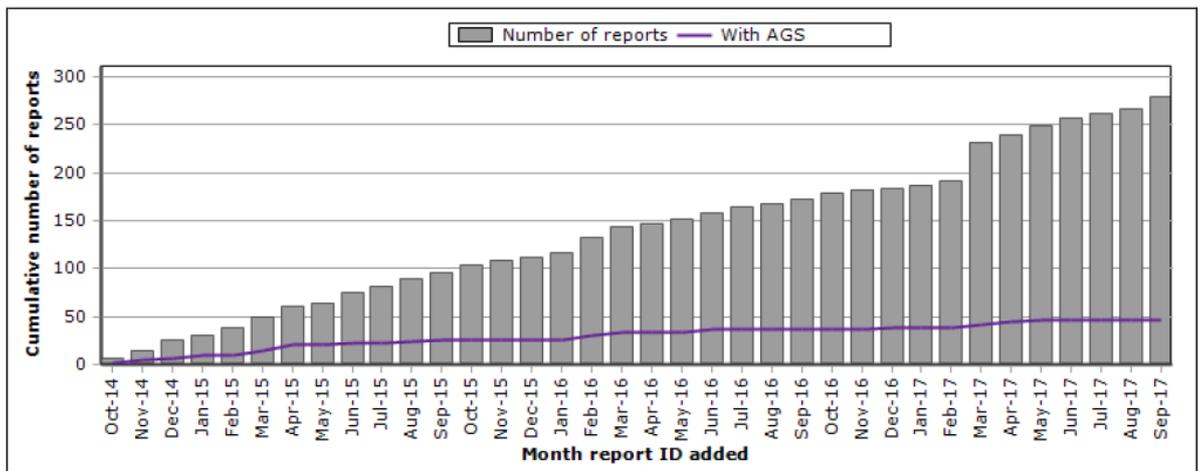


Figure 1 AGS data population

The exact reasons for the discrepancy are not known, however anecdotal evidence indicates that the data is being produced by the contractors, but not being uploaded by the Engineers.

This may be due to not understanding the requirements or poor quality data (HAGDMS automatically checks AGS data files and rejects them if they do not comply with the AGS data format rules and the database requirements.) It may also be due to the fact that AGS data cannot be viewed by Highways England staff, nor is it seen by Highways England staff as the supply chain.

If (historical) AGS data format files exist on or near a proposed scheme, the data is extremely useful for early management of ground-related risks on projects for creating ground models of the geology and geotechnical properties. It can help plan an investigation and inform of likely solutions and hence costs.

4.2.3. Quality of AGS data

The baseline review found that AGS data, whether in HAGDMS or from other sources, is a high value resource, when available. However, the quality of older 'historical' AGS data can be variable, leading to a need to carry out some re-processing of the data. Common problems include:

- General missing data
- Inconsistent use of soil material codes
- Inconsistent use of other codes, e.g. hole or sample types
- Missing co-ordinates or levels

- Missing or incomplete groundwater monitoring records

A further problem, evident upon review of the data found in HAGDMS, is that despite the AGS version 4 standard being released over seven years ago, Highways England is only just starting to receive files in that format. This is concerning because AGS4 was created to reflect the data required to be reported in EC7 and associated standards. The reasons for this slow uptake are not fully understood although the need for software houses and suppliers to upgrade their software and systems to accommodate the significant changes inherent in AGS4 may have been a major contributory factor. It means that there is a gap between the information reported (in the PDF factual report) and that contained in the AGS data format (version 3) files. When trying to re-use the files, this gap would need to be addressed and plugged, if necessary.

Historical AGS data and "new" AGS data format files digitised from (historical) exploratory hole logs has been utilised for the Smart Motorway Programme. This was of considerable use, however feedback from the exercise suggests that richer information should have been extracted, including laboratory test information. The issue of the discrepancy between the report and AGS version 3 files may need further extraction of information if the work were to be repeated.

The baseline review for ground investigation (section 3.3.3) identified issues relating to the quality of AGS data. Those findings are repeated here:

Some of the inconsistencies seen between AGS files are the result of inconsistent or incomplete specifications. The AGS documentation does not provide a full specification and the Highways England Specification for ground investigation (Highways Agency, 1997) provides limited further definition, with the full specification left to the specifier. The most obvious example of inconsistency is soil material codes. However, some problems are caused by inconsistent referencing of exploratory holes, tests and samples. IAN 184 (Highways England Data & CAD Standard -2016) specifies AGS 3.1, or greater. This should be updated to AGS 4.

Checking of AGS data remains a challenge. Proprietary checkers only check compliance with format rules. The completeness check, i.e. does the data include everything in the factual report (except for identified exclusions). The Highways England Specification for ground investigation clause 12.4.7.4 requires the "Digital Data Report" to identify where "data are included as a paper record but are not included in digital form", but no examples of this being applied have been seen. Accuracy of the data, i.e. is it the same as the paper copy, relies upon the data and factual report being produced from the same version of the same database.

4.2.4. Extending the use of the AGS data format

AGS4 was the first version to facilitate the exchange of laboratory test scheduling data. The HS2 project requires its supply chain to use AGS data for laboratory test scheduling and has worked with one of the major software suppliers to develop tools to facilitate its use. However, outside of HS2 its use within the industry appears to be rare.

The AGS format is not explicitly designed to accommodate exchange of ground investigation schedule information, i.e. exploratory hole references, types, location, depth etc. However, there is anecdotal evidence that some specifiers have used it for this purpose.

As noted in the baseline review, use of the AGS format for exchange of monitoring data that is not part of a ground investigation appears to be rare – both of Highways England projects and within the industry in general. It is known that it was used on the Crossrail project, albeit not in the way that was originally envisioned on that project.

AGS data is not yet capable of supporting transfer of construction data but there are some current AGS supported initiatives relating to extension of the format to cover piling, grouting and sprayed concrete lining tunnels. These are further discussed in section 6.

4.2.5. Discussion and recommendations

Current use of AGS data in Highways England

Whilst use of AGS is well established within the supply chain in Highways England, the review has identified that improvements can be achieved. Those changes to the AGS format itself are discussed in the section that follows this; but changes that should allow improvement that to be achieved now are described below. These include some recommendations identified earlier in this report.

Consistent specification helps everyone in the supply chain, especially ground investigation contractors. Specific recommendations relating to the specification of AGS data:

- Ensure that all data is provided in AGS v4 to comply with Eurocodes & associated ISO standards. Updates to Standards, IANs and EIR required.
- Review Highways England use of abbreviation codes in AGS format data, including soil material codes. Aim for a consistent specification that is fully aligned with AGS and, preferably, also aligned with BGS and other asset owners.
- Improve Highways England specification requirements for AGS data. Address concerns relating to inconsistencies in referencing and abbreviations. Incorporate existing AGS guidance and/or create new guidance. Consistent specification helps everyone in the supply chain, especially ground investigation contractors.
- Encourage exchange of laboratory test schedule information as AGS data (format already exists).

Data in the AGS data format is very valuable to Highways England. It provides input to future projects via the desk study process and can reduce costs during ground investigation and throughout the asset management processes. There is also the potential to analyse data across projects, perhaps by region or nationally. For example, large data sets could be analysed to re-assess correlations between in-situ test data, laboratory test data and asset performance. Such analysis could be done by Highways England, suppliers or external organisations given access to the data such as academia or research bodies. Data held by other infrastructure owners could also be used at the national level.

To enable Highways England, its suppliers or others to realise the full value of the data, the data needs to be of good quality, preferably using consistent coding, and easily accessible. The above recommendations regarding specification of future data should lead to improved data quality. The following further recommendations will further help increase the value of the AGS data held.

- Improve the process of AGS data upload. AGS data is frequently not uploaded to the asset information system in a timely manner. Implement processes for audit and improvement. This ties in with recommendations relating to the overall data management system.
- When AGS data is digitised from PDF reports, the complete data set should be digitised, not just logging data.
- AGS data to be made easier to access by combining all data sets and enabling user to download data from selected exploratory holes, rather than on a project-by-project basis.
- Provide access to Highways England AGS data for research purposes to provide information that will help design.

Future development of the AGS format

It is considered highly likely that AGS will continue to be the primary transfer format for ground investigation data in the UK, although it is also likely that it may evolve in response to trends and developments in the data format domain. As a major generator¹² and consumer of AGS format data, Highways England should play a leading role in the further development of the AGS format. For any major changes or enhancements, Highways England could assist by drafting proposals as part of Highways England projects, then taking them to AGS for adoption. This would considerably speed up the process of change given that AGS often lacks the resources to work up major changes in a timely manner.

Specific recommendations relating to the development of AGS are given in the following (some are a repeat of recommendations made earlier in this report):

- AGS data to eventually become the primary deliverable from a ground investigation, with the report a secondary view of that data. Requires further development of AGS format, as discussed later in this report (Section 6.4.2).
- Adopt web-friendly (JSON¹³) data interchange formats for general data transfer, including AGS format, possibly co-existing with the current format for an initial transition period.
- Develop the use of AGS format for issue of hole scheduling information to ground investigation contractor. This will require revision of the AGS format as this is not included at present, albeit it can be done now with some imagination. This will promote the importance of structured data exchange and should lead to consistent hole referencing.

The following recommendations (repeated from earlier) are made regarding the use of AGS format for capturing monitoring data:

- Review suitability of current AGS format for monitoring data and, if necessary, recommend improvements to AGS.
- Following on from the above review, promote the use of AGS format for exchange of construction monitoring data.

¹² via its supply chain

¹³ JavaScript Object Notation

The AGS Data Format Working Group is currently looking at extending the scope of the data dictionary to include works such as piling, grouting and tunnels. The following recommendations (repeated from earlier) are made regarding the extension of AGS format to construction activities:

- Extend the AGS data format for use in earthworks compliance testing and other geotechnical construction activities. For example, recording number of passes of a roller, or in-situ density testing of earthworks layers.
- Support current AGS work on format for piling data (current part of Highways England structures remit, but of interest to geotechnical engineers)
- Support current AGS work on format for grouting data. Identify other processes that may benefit from AGS format data.

Whilst it may be possible to record this information in AGS format, the question should be whether as-built information should actually be captured in a format that better interacts with the data requirements set out in PAS 1192 (BSI, 2013)

There may indeed be a case for having the information in both formats, to reflect the different requirements of different users of the data. For example, the detailed geometry and form of assets is best captured via the design/construction CAD/BIM models used, for which use of IFC is recommended (see Section 6.3.1). However, AGS format or similar, is well suited to capturing the data that might be collected during construction of the assets, e.g. records from piling, or earthwork compaction records, as applicable. The data sets would ideally be linked, sharing common metadata.

Note that some or all of the above recommendations could be combined into a sub-group of the Asset Data Improvement Group, organised by AIG.

4.3. Access to information

4.3.1. Supply Chain Portal

The Supply Chain Portal was reviewed to determine the availability and access to information. The Portal provides useful links to the standards, the ADMM and third party information such as the GeoStore, but in general the amount and scope of information is quite limited and could be improved.

The following should be considered for inclusion on the Portal:

- Guidance notes e.g. geotechnical inspections
- Registers of training/GeoAMP submissions etc.
- Asset performance reports. e.g. Monthly Report
- Process charts e.g. requests for data
- Geotechnical and related asset management upcoming events
- Spreadsheet and software tools (e.g. data analysis tools)
- Organisation charts

The principles for inclusion of information should be that information that would be of use to the non-geotechnical as well as the geotechnical community. Access to the Portal is restricted to Highways England and its supply-chain only, so

information that has a wider audience should be held on an appropriate system, either the Highways England Web Site (e.g. Research Reports) or on HAGDMS "open pages".

The following comments and recommendations are largely based on direct feedback from practitioners in the supply chain.

Highways England's supply chain requires access to information for the following purposes:

- operational management (inspection scheduling, works planning)
- project activities (H & S information)
- compliance with standards
- Toolkit - shared best practice/efficiencies
- performance management
- tendering

Currently direct suppliers are given access to HAGDMS, however evidence collected as part of this task demonstrates that suppliers further down the chain such as ground investigation contractors do not. These ground investigation contractors are often acting as Principal Contractors under the CDM legislation.

Highways England have a duty as a client under CDM (2015) to provide all relevant information to the Principal contractor. This may currently be happening via other suppliers on a contract, but it is not transparent and demonstrable.

It is recommended that access to HAGDMS is given to Site Investigation contractors to ensure that they have all available information prior to commencing works on site.

4.3.2. Highways England website

A review of the ability to access information using the external-facing Highways England web site was carried out. The review showed that the current web site was very difficult to navigate. A Google™ search provides the following, different domain names for the first three "hits":

- www.gov.uk/government/organisations/highways-england,
- roads.highways.gov.uk
- www.highways.gov.uk

The first and third links take the reader to the main Highways England part of the Government web site.

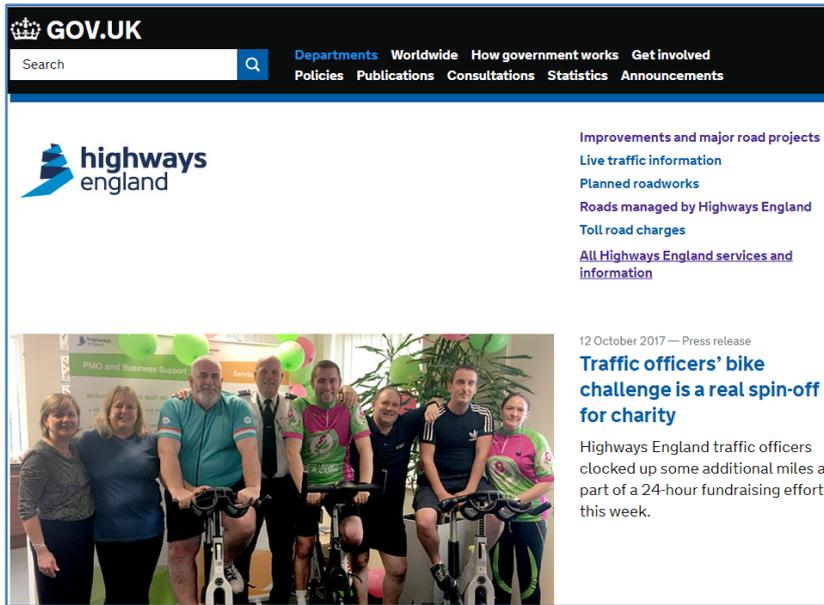


Figure 2 Highways England main site

From here the only link to other information, which may seem suitable is "Services and information", however the resulting web page doesn't yield any useful results.



Figure 3 Highways England services and information

The second web site shows the "Improvements and Major Projects".

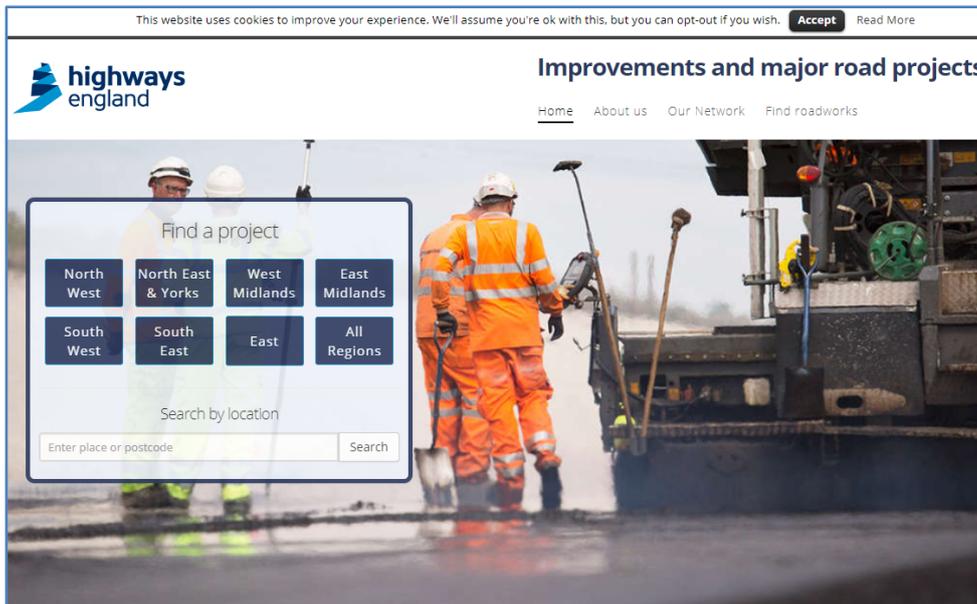


Figure 4 Highways England - Improvements and Major Projects

This page is maintained by the National Traffic Operations Centre and has no obvious links to any geotechnical or other technical related information.

If the user searches for "*research Highways England*" the results are more promising. The first three results are to the following links:

- www.highways.gov.uk/knowledge
- www.highways.gov.uk/knowledge/strategic-research-framework
- <https://www.gov.uk/government/organisations/highways-england/about/research>

The first web site is the Knowledge Compendium, which presents a searchable database of research projects. The metadata includes scope, and reports are available for download.

A search for "*geotechnical*" in the Compendium web page yielded fifteen results of which seven had reports dating from 2010 to 2017. This appears to be an incomplete listing of the research reports carried out within that period. The index is difficult to navigate, requiring multiple mouse clicks and downloads to determine if the reports are relevant.

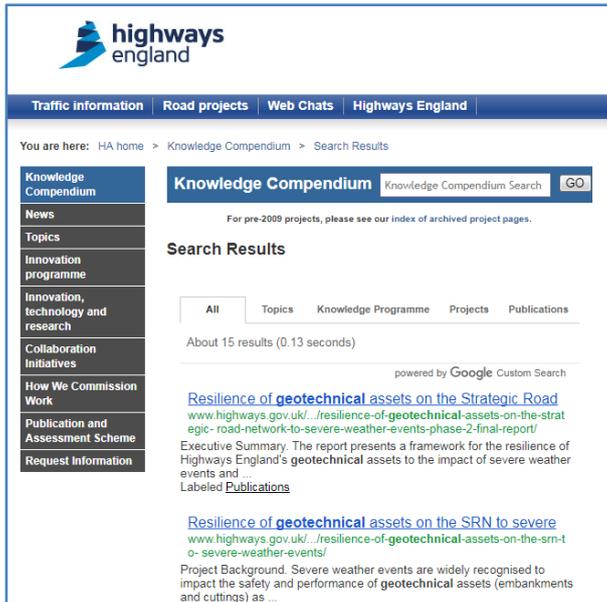


Figure 5 Highways England Knowledge Compendium

The final listing in the Knowledge Compendium provides a link to the Pre 2009 projects, which are hosted on a National Archives web site. The listing is in alphabetical order and is not directly searchable for words, either in the title or the metadata.

Selecting the entry [Update of RR 199 \(earthworks\)](#) takes the reader to an error page, which is the same for all the listings.



Figure 6 National Archives Error Page

4.3.3. Managing Down Costs Toolkits

Several years ago the Highways Agency developed a series of "Toolkits" with the intention of disseminating best practice and innovation to reduce costs. A search was made for these "Toolkits" on the internet. They were eventually found on the National Archives Web site and on the current highways.gov.uk web site at this address:

<http://www.highways.gov.uk/specialist-information/highways-agency-toolkits/the-managing-down-costs-toolkit/>

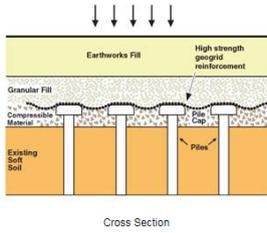
The web page of an example Toolkit is shown below:

Safe roads. Reliable journeys. Informed travellers

HIGHWAYS AGENCY

Managing Down Costs on Highway Schemes

Idea 250 – Earthworks basal layer suspended over piles for accelerated construction



Cross Section



Description of Idea

By constructing a piled foundation with a geotechnical load transfer platform over the soft subsoils, the need for long settlement times is avoided. The pile load transfer platform geogrid reinforcement could be placed directly on the pile cap and works in a hammock effect (See Cross Section). See also [MDC249 – Pile supported earthworks for accelerated construction](#) alternative.

Applicability

Construction of embankments on soft ground. Could be combined with [MDC241 – Reduction of Reinforcement in Embankment Piles](#)

Figure 7 Managing Down Costs Toolkit Idea 250

Anecdotal evidence from discussions with some of the Highways England Geotechnical Advisors shows that these resources are not widely known. The difficulty finding the web pages would suggest that unless the user is aware of the resource, they would not be able to discover it.

4.3.4. Knowledge Bank - Innovation

The following site was discovered whilst searching the Internet for geotechnical resources linked to Highways England and Geotechnical Engineering:

<https://kol.withbc.com/HA-Knowledge/>

It is a live site set up by Balfour Beatty for Major Projects Directorate. It does not have an official Highways England URL address.

Knowledge Bank

Highways England - Knowledge Bank

Open Knowledge Bank

Useful Documents

[Guidance for Submission](#)

[Verification Group ToR](#)

[Efficiency Manager ToR](#)

[Knowledge Process](#)

Useful Links

[Highways England - Lean Tracker](#)

Help

If you encounter difficulties using the Knowledge Bank or have a comment or suggestion, please contact Highways England Knowledge Team: [Contact by Email](#)

Data Protection

The records and information in this database is owned by Highways England and hosted by Balfour Beatty.

This database is intended for use only by authorised business partners of Highways England for the purposes of reporting and sharing of knowledge

Within the Knowledge Bank there are innovations relating to geotechnical engineering, as shown below:

Unique ID	Created Date	Original No.	Project	Title of initiative	Summary of initiative	Status	Verification Group Comments
702	14:21:13, 10/03/2017		M1 Smart Motorway J32-35a	The use of GRIP piles as an alternative to concrete bored piles.	<p>GRIP piles are a form of helical pile that the Contractor proposed for use where ground conditions (in this instance shallow rockhead) prevented the installation of traditional helical piles. The use of traditional helical piles removes the need for temporary works, however the rig required for the installation of GRIP piles requires temporary works which are similar to those for concrete piles.</p> <p>GRIP piles are unable to penetrate as deep into hard ground as concrete piles, therefore more are required to provide the required design resistance. This results in the GRIP pile foundations having a bigger footprint than a traditional concrete piled foundations. Due to the bigger footprint of the foundations the amount of temporary works required for GRIP foundations is bigger when compared to the concrete piles.</p> <p>The original scheme design included only for concrete bored piles. The Contractor proposed helical piles as an alternative method. The justification for using helical piles was the removal of temporary works required for concrete piling.</p> <p>Cost analysis compared the installation of helical piles with concrete piles. The temporary works for the installation of concrete piles was priced at £10k per foundation by the contractor. Therefore, for the cost analysis £10k per site was added to the concrete pile installation. At the time of the cost analysis the Contractor did not appreciate the temporary works requirements for GRIP piled foundations, therefore the cost of these temporary works were not taken into account during the cost analysis.</p> <p>The risk of hard dig conditions (shallow rockhead) was not considered by the Contractor when assessing the use of helical piles. The helical piling specialist the Contractor appointed to undertake the design and installation provided appropriate foundation solutions for all sites. Due to the shallow rockhead underlying the scheme, a significant number of the designs provided by the helical piling specialist were GRIP piled foundations. The additional temporary works and cost associated with the GRIP piled sites were not fully understood until the construction began.</p> <p>Observations made during the construction phase of the scheme show that the GRIP piled foundations require similar temporary works to the installation of concrete piles. In addition, due to the shorter length of the GRIP piles, more are required creating a bigger footprint for the gantry foundations. It is considered that the use of GRIP piles as an alternative to concrete piles in hard ground do not provide any technical, financial or programme benefits to the scheme.</p>	"Submitted for Verification"	
680	10:52:20, 14/09/2016		A21 Tonbridge to Pembury	Removal of Hazardous Contaminated Material	<p>Construction on the A21 site has uncovered several areas of Hazardous Contaminated Waste, some of which is Friable Asbestos.</p> <p>This has taken a considerable time to start the removal process and a number of lessons has been learned along the way.</p> <p>The process is being documented and reviewed, should further instances of Contaminated Waste be found on this site or any other site in the future.</p>	Pending	VG need to see the final process when the documentation has been drawn up to be able to make an informed decision on this process, once the VG have all the details they can then refer it to the relevant expert for the decision

Because the web site is not within the “.gov.uk” domain, it is unlikely that the existence of this web site is widely known within the Highways England supply chain and other stakeholders.

4.3.5. Recommendations

It is recommended that a review of the information on the various Highways England internal and external web sites be carried out and a strategy for holding and disseminating the information be drawn up. Ideally the archived information should be collated, so as not to lose it. As a minimum, short-term measure a list of relevant links to the various web sites should be created and held on the Supply Chain Portal.

4.4. Procurement Review

During the course of discussions with the Smart Motorway Peer to Peer Group, and through feedback from Geotechnical Advisors it became clear that procurement of ground investigations was a recurring problem. Having an efficient and well-specified procurement process enables the collection of information to be of the correct quality i.e. timeliness, completeness and accuracy.

Evidence from the Peer to Peer group indicated that the procurement process was a significant stumbling block to timely delivery of information during the project and hampered the designer’s ability to provide the required quality work and risk mitigation.

At the time of the review investigations were being procured via the main contractor, which is typically at a late stage in the project design stage. The reasons for this are:

- Highways England does not have a ground investigation framework contract in place
- Consultants are unable or unwilling to take on the role of Client (CDM 2015)
- Network occupancy must be minimised
- Cost
- Logistics of organising traffic management

The impact of poor procurement was recalled by one interviewee who is part of the Smart Motorway Programme. They outlined an incident where the site investigation contractor had been employed by the main contractor under a lump sum, per borehole basis. Any changes to the borehole had to be agreed with the main contractor and Highways England. This led to delays in the investigation and inevitably a loss of information, due to the constraints.

The use of framework contracts by major infrastructure clients is fairly common. HS2 used a framework to procure the site investigation works and the Environment Agency and utility companies have frameworks.

- The key advantages of a framework in terms of information are:
- Data and report formats can be standardised
- Timeliness for delivery of information can be specified consistently
- The supply chain can develop systems to support the data and reporting requirements, resulting in increased data quality
- The supply chain can document processes in accordance with BS8574 and link them to Highways England processes in a consistent way, ensuring that roles and responsibilities are well established and communicated.

In February 2015 HS2 appointed nine contractors to its site investigation framework, whilst the Environment Agency established the National Site Investigation Framework (NSIF3) Framework to provide access to contractors who routinely provide investigative services such as boreholes, trial pits, and material testing in preparation for the design and construction of projects. The duration of NSIF3 is a period of 4 years commencing on 4 April 2011, with an estimated value of £5million.

"The aims of the framework are to:

Add value by helping to design a site investigation to provide the most efficient choice of plant and method of information recovery, so that both designers and contractors get the most appropriate amount of information they require to do their job.

Carry out work competently and safely. This means all site supervisor staff have obtained a certain level of qualification and experience to give a safe service.

Reduce and manage risk. Apart from the national coverage provided by the five site investigation contractors, we have access to four specialist companies providing Buried Services Surveys and Un-Exploded Ordnance (UXO) assessments."

Extracted from "Current Issue 1 2013": [Link to "Current" magazine download](#)

Other major infrastructure clients such as city councils (e.g. Glasgow City Council) also let ground investigation frameworks.

Frameworks do carry their own risks, for example

- sub-contracting,
- trying to fix rates for periods considerably longer than likely fluctuations in GI rates leading to 'unavailability' of plant,

- variation site to site needing 'mini competitions', etc.

These all need to be recognised and managed.

4.4.1. Recommendations

It is understood that there is an ongoing activity to look at the use of a ground investigation framework contract in Highways England. Depending on the timing of a possible framework contract it may be useful, in the interim to provide a short guidance note on the procurement of ground investigation. The emphasis should be twofold:

- All investigation works should be based on re-measure
- The designer of the ground investigation must be as close to the procurement and management of the site investigation contractor as possible.

The objective of the guidance note is to inform non-specialist procurement teams about best practice and the requirements of Highways England and its supply chain.

When preparing a framework contract it is strongly recommended that other infrastructure owners are consulted to establish best-practice. The supply chain, including ground investigation contractors should also be consulted to ensure that it is fit-for-purpose.

5. Review of Highways England internal initiatives

5.1. Introduction

A review of relevant tasks and activities that have/are being carried out by Highways England was undertaken. The findings from task reports were reviewed and any outstanding, relevant recommendations collated and brought forward as recommendations from this task. These are presented in the Work Bank in Part 1 and form a valuable, categorised single source of actions to improve geotechnical information in Highways England.

5.2. Review of HAGDMS and Asset Information Requirements

The structure of the database which holds the geotechnical asset information in HAGDMS was developed in 2000-2002. It was at a time when asset management was in its infancy and the decisions made were taken to reflect mainly paper-based ways of working with a focus on the technical aspects of the asset, rather than the operational, or high-level decision making and reporting requirements. Since 2002 the awareness and requirements of asset information have changed. Whilst there have been some changes in the software to reflect those changes the information requirements as a whole and the schema of the database have not been reviewed.

HAGDMS currently has limited scope to include some existing and new business requirements, due to resourcing and technology constraints. Highest priority of these is the (lack of) ability to refresh the road network such that it represents the current information. The inability to do this means that new (offline) assets cannot be snapped to the network with the result that data quality is compromised and reporting is therefore increasingly inaccurate. HAGDMS currently uses the Ordnance Survey Integrated Transport Network (ITN) as the base network. This will need to be migrated to the IAM IS (Integrated Asset Management Information System) network at some point so that all the assets are using a common referencing system. There are some challenges regarding junction layouts (primarily slip roads) that need to be addressed during migration. The IAM IS network will be updated monthly, therefore a method of updating the base network in HAGDMS may need to be developed, depending on business requirements/programme scheduling.

Other data quality issues are caused by the inability to record inventory and condition data at the required level of granularity and the schema of the database makes it difficult to properly separate inventory and condition data.

The mapping engine in HAGDMS is relatively old technology and requires static data snapshots rather than "live" dynamic maps. This creates a timeliness quality issue and requires human intervention to ensure that it's maintained.

HAGDMS has some very useful and powerful query and reporting tools, but the full extent of the data cannot be accessed via the queries or searches. Instead a data snapshot needs to be taken at quarterly intervals for subsequent download and analysis. The format of this download is defined in the ADMM (V5+). It would be far easier if either the snapshot could be queried directly, or the searches were expanded to negate the need for a snapshot.

HAGDMS currently does not have a roll-back facility, i.e. to view the database at a particular point in time. This is essential for an asset information system, to be able

to track changes in the network condition (deterioration modelling, see also Section 6.15) and associated works.

The system also does not have the ability to carry out "dynamic segmentation" i.e. to locate assets or other items relative to the network.

Highways England will need to replace HAGDMS by 2020 due to software and security vulnerabilities. At the time of writing a target date for the roll out of the national geotechnical stage of IAM IS is set as September 2019. Whether or not HAGDMS is superseded by IAM IS, the existing product will need to be replaced or renewed.

A change in software system provides an ideal opportunity to undertake a detailed review of the information requirements and to plan a database schema that best reflects those requirements. The sort of problems that need to be addressed are the mix of inventory and condition data and the lack of cost information.

The process of creating a schema should take into consideration the following:

- Alignment across assets
- Use structured data where possible
- Ensure asset history is maintained

It is strongly suggested that the approach taken to determine the information requirements should be based on the model where questions that need to be answered are defined and the data that lies behind the answers is established. The questions should be themed using the following:

- who
- where
- what
- when
- why
- how
- how many
- how much

For example questions could be:

- "who" is responsible for maintaining the asset?
- "how" do I gain access to my asset?
- "when" does the asset need to be inspected next?
- "what" is the rate of deterioration of an asset?

By examining the questions and the information that lies behind the answers a complete set of data can be derived that isn't focussed just on technical information, or inventory and condition information. It can also help determine the required quality of the data such as timeliness and accuracy and hence the resources required to capture and maintain the data.

Ideally this will be carried out at a cross-asset level, because many of the high-level questions will be the same for all assets. This will help to ensure consistency of data and database schema.

5.3. Asset Information System, Benefits Realisation

A benefits assessment was carried out by Arup in 2017 to audit the documented benefits that have been used to support various business cases for HAGDMS/HADDMS. The benefits list had been used for several years to justify investment for the maintenance of the HAGDMS/HADDMS Asset Information System.

The benefits assessment considered the calculations used and the justification of the inputs. One of the key findings of the assessment is reported below:

“Demonstrable usage (e.g. ‘active users’) will be an important part of future business cases. The following measures could be added to the ‘System’ to record additional usage data to support benefits measurement (capture efficiencies):

Number of asset dataset and document downloads. Future updates of the System should capture download information as an indicator of data access / use. This could include such as query or report name, date, type of record (e.g. as-built record, geotechnical design report, etc.). Additionally it would be beneficial to capture information on the reason for download (e.g. route assessment/desk study, inform new design, maintenance intervention).

Site usage data to understand the level of usage of the various features; for example pages visited, time spent on pages of visits, etc. This information would provide both benefits metrics and also inform system development.

User type and requirements. A ‘pop-up’ user survey could be added after report upload/download to capture information on user profiles and why they are using the System. This information would provide key metrics on site usage and enable continuous improvement.

Periodic feedback surveys from the suppliers and service providers, again contributing to continuous improvement.”

The collection of usage information to support the business is often overlooked when developing software systems. However, it is extremely important in the justification for the ongoing maintenance and support of those systems.

Consideration of the usage metrics and the requirements specification of IAM IS or the HAGDMS/HADDMS legacy system should be included in any asset information development activities. This should not be confined to the geotechnical and drainage assets.

5.4. Analysis of GAD Data

The Geotechnical Asset Database (GAD) system holds large amounts of data from inspections carried out since 2002. This information can provide valuable knowledge regarding the performance of the asset to enable smarter reporting and decision making. Whilst HAGDMS provides a variety of searches and charts, it can't currently perform detailed analysis of the data. It is recommended that offline data analysis be carried out to present charts used in reports where time series

data is required e.g. spending reviews, setting budgets for road periods and performance reporting.

The tools should be developed using the following guidelines:

- Open source
- Commonly available development languages (Python, R, html, JavaScript etc.)
- Use standard data structures
- Cross platform (Windows, Mac & Linux)
- Able to be run from the command line
- Use standard data exports/search downloads (csv,JSON etc.)
- Well documented
- Report-friendly. i.e. output in graphical/and or text format for inclusion in reports
- The output should be GIS-friendly where spatial analysis is required

In addition, tools should be created to convert/transform downloads and data extracts into "standard" data structures with appropriate headers (keys) such that they can be used for data analysis. This would avoid people having to manually transform data.

The development of these tools should be carried out with the awareness of the HAGDMS/HADDMS and IAM IS asset information programmes. The development should also consider how cross-asset information can be combined (e.g. pavement condition data with geotechnical condition) to maximise the potential for integrated asset management.

All tools should be made available to the supply chain, either on the Supply Chain Portal or in web-based version control systems some as GitHub. Additionally the tools could be provided as a web application. This will make the use of the tools easier, especially where installation of software is difficult, due to security reasons.

The use of interactive data visualisation libraries such as D3 ([D3 - dashboard - example](#)) will enable the user to explore the data and reduce the need for visualisations using pre-defined parameter limits.

5.5. Geotechnical Drainage Information

Geotechnical drainage is not explicitly defined, but it is deemed to include any drainage features that are designed as part of an earthwork (including capping materials) to maintain or improve its stability, rather than take surface water away from the road pavement. Drainage is a key aspect of an earthwork system. The omission of this important information is a significant hindrance to the assessment and maintenance of the earthwork assets.

Currently information relating to geotechnical drainage is not fully presented as structured data. Some data is held, but it's very high level and not well defined either logically or spatially.

Geotechnical drainage information is present in the Highways England drainage asset information system (HADDMS) as structured data and on drawings. It is also

present in the pavement asset information system, in AVIS and possibly other operational data sets.

It is recommended that the geotechnical drainage information be improved by carrying out the following activities:

- define - what constitutes geotechnical drainage & where is the interaction with pavement drainage?
- specify - structured data requirements
- collate - gather data from the available resources, including remote sensing, AVIS etc.
- maintenance - determine maintenance requirements
- inspections - define inspection requirements

It will be necessary to discuss the drainage asset with representatives from other asset classes in order to agree maintenance responsibilities and definitions and to avoid duplication and/or omission.

5.6. SGM Task Review

A research task (TTEAR Task 594) Special Geotechnical Measures (SGMs) was carried out by Atkins on behalf of Highways England. The output was a report, issued in August 2017. The objective of the task was to "mine" information from the structured data on HAGDMS to tag assets with SGM data.

A Special Geotechnical Measure is defined in the report as:

“Special Geotechnical Measure (SGM) - Measures over and above traditional earthworks construction required to, mitigate geotechnical risk associated with ground related hazards or remediate geotechnical defects that may have resulted from the presence of geohazards. Similar techniques implemented to facilitate widening or improvements are also classified as Special Geotechnical Measures for the purposes of this task.”

The task also looked at how information contained in the text and metadata of the report records could be extracted and used to enhance the metadata with keywords, such that reports could be searched more efficiently for relevant information relating to SGMs.

The key findings of the task are presented below:

“This research has successfully developed data mining methodologies that have addressed and overcome a number of the limitations encountered during Task 416 [a previous task]. Although the task has experienced a number of limitations of its own, the project has been successful in generating a summary of design and construction reports, verified to likely contain information concerning the construction of SGMs across the network. A geospatial data set of SGMs identified from within the existing structured inspection data has also been produced. Together these two data sets will dramatically improve Highway England’s knowledge of where SGMs exist within the geotechnical assets that they own and will support a proactive approach to their management and maintenance in future.

The methodologies have effectively identified 93 No. different types of SGM within 3,169 No. pdf Reports, and 72 No. SGM types, representing 9,833 unique SGM extents, covering approximately 1,300 km of earthworks, from within the existing electronic asset information.

This task has gone on to interrogate the outputs of these data mining methodologies, to further enhance the quality of the data sets, search for patterns in performance and understand potential network risk.

A substantial element of this work, beyond the production of an enhanced digital data set, has been a critical review of how geotechnical asset information is currently captured and managed by Highways England. Recommendations have subsequently been presented to address how these systems could be improved to enhance the collection and management of SGM information and analyse asset lifecycle performance in relation to network risk."

The report presented the mined structured data as a data set of observations with derived start and end co-ordinates, where SGMs overlapped. This data set is scheduled to be uploaded as a mapping layer on HAGDMS. The codes used to denote the SGMs are also due to be included in the "description" field of the observation structured data, to enable searching. The use of the "description" field is a workaround due to the limitation of not being able to update the HAGDMS software. It should not be perpetuated in a replacement system.

The information obtained from the reports was presented as a list of the report IDs and potential SGMs. It is the intention to populate the Report metadata with this information, however it will require the SGMs to be grouped into "SGM Sub-Categories" due to limitation of the HAGDMS software.

The Report provided the following findings:

Table 1: Excerpt from Task 594 SGM final report (Atkins, 2017)

Focus	Recommendation	Delivery
Structured Data (Geotechnical Asset Data)	Incorporation of identified SGM types into observation summary data	Use of Task output to identify existing observations containing record of SGMs.
	Production of static SGM data layer	Use of Task output to visualise locations of derived SGM extents.
	Incorporation of derived SGM extents and key attributes into Geotechnical Asset Database	Use of Task output to generate derived extents of SGMs as a unique observation within the asset record. Addition of multiple new SGM specific data fields.
	Adoption of SGM hierarchy	Incorporation of SGM hierarchy into data capture / reporting of SGMs.
	User defined SGM reporting/searches	Development of systems functionality to search SGM related data fields and visualise outputs.
	User defined SGM reporting/searches	Development of Topic Search tool, relative to SGM observations.
	Improved data linkage / relationships	Development of systems functionality to link multiple observations, and reports to observations.
	Update SGM inventory	Application of methodology to observations recorded since date of task data extraction.
Unstructured Data (Reports)	Incorporation of verified SGMs into Reports summary	Use of Task output to identify reports likely to contain location/details of SGMs.
	User defined SGM reporting/searches	Development of Topic Search tool, relative to SGMs verified reports.
	Additional structured data capture	Development of systems functionality to allow capture of additional data fields, including association of SGM type to reports.

Some of the recommendations provided above cannot be achieved with the current geotechnical asset information system, but should be included in any replacement.

There has been liaison with the data hand-back task (see Section 5.11 below) in order to capture the data and information that is possible at the moment. There also needs to be liaison with the HD22 review team, and the ADMM to ensure that the information is specified appropriately.

The categorisation of the SGMs provided in the report does not necessarily reflect the construction, as-built or operational information requirements. Further work will be required to the categorisation, for example to determine which of the SGMs relate to as-built geotechnical inventory, which to temporary works (e.g. surcharging) and which to structures (e.g. Secant Bored Pile Wall).

The SGM categorisation should be checked against the other asset classes in the ADMM to ensure that there is common terminology and to avoid duplication or omission.

The work that was carried out as part of Task 594 was undertaken on data sets that are a few years (snapshot of 22nd of May 2015 for structured data) old and

pre-date the issue of HD41/15. Therefore work will be required to update the current data sets using the methods set out in the Task 594 report.

Follow on from Task 594 and earlier studies, SPaTS Task 1-456 'Geotechnical Whole Life Assessment' recently started looking at evaluation of (including SGMs) current and future performance of geotechnical assets. The project will be drawing on condition, survey, and investigation data captured by Highways England as well as the outcomes from related academic research and collaboration/exchange with other transport infrastructure owners. The project will also attempt to evaluate deterioration of geotechnical assets, particularly for SGMs.

5.7. Review of IAM IS Requirements

The functional requirements for IAM IS were set out in 2012. These were updated for specific geotechnical requirements in 2013. Those requirements were established largely based on the existing requirements of the legacy systems. Since they were documented the business has become a regulated company and has progressed along the asset management maturity model.

Whilst the core of the functional requirements should not have changed it is important to refresh the requirements to ensure that development of the IAM IS system is aligned to the current and future business needs.

Particular attention should be paid to searches and reports. The topic search in HAGDMS is relatively new functionality that may not be reflected in the original IAM IS requirements.

Part of the development of the IAM IS system will be configuration. This includes the definition of the data tables and fields (schema). The existing HAGDMS schema is the IPR of Mott MacDonald, so it won't be replicated in IAM IS. This creates an opportunity to create a schema from scratch to meet the business and data requirements and to align to the other asset classes.

This is quite a substantial effort that requires careful thought, planning and testing. It can mostly be done without access to IAM IS so it is recommended that this exercise be carried out as soon as possible. The output could also be used if HAGDMS is updated in the medium term to long-term, so the effort would not be wasted. The focus should be separating the inventory, construction and condition data into a logical hierarchy, but there are many other things to consider.

5.8. Review of HD22/08

Highways England is in the process of reviewing their standards to enable a consistent approach and provide the ability to update the documents in a more timely manner. The documents will also be made available via web pages rather than PDF files. This will enable readers to search through the documents in a smarter way.

The review includes all the geotechnical standards and guidance, including HD22/08.

SES Geotechnics are currently reviewing HD22. The high-level reporting and certification requirements in the revised version of HD22 remain largely unchanged from the previous version, however the format of the reports has become less formulaic to enable flexibility of reporting.

The profile of the geotechnical risk register has been raised, with an example Excel template provided.

AGS data files are specified for the factual report stage, (Ground Investigation Scope Report and Ground Investigation Report) but not for other stages.

The impact of HD22 on the existing geotechnical information requirements is considered to be minor. However, there are areas for the improved capture and reporting of data, as follows:

- The status of the geotechnical certificate could be held as structured data
- The certificate could be managed as an electronic form, rather than a PDF, as long as the authorisation was dealt with effectively to replicate a signature, e.g. use login and authorisation credentials to digitally authorise the issue and receipt of a certificate.
- The risk register could be web-enabled such that it is available to all parties at any point in time, with snapshots recorded at key reporting stages. Version control and roll-back of the register would be very useful.
- It is likely that with the flexibility allowed in the new version of HD22 different report formats will be issued, particularly with the increased use of GIS and mapping tools. Systems should be designed to handle the native data formats as well as the final PDF version of the report. Native file formats should be non-proprietary to ensure re-use in the medium to long-term and to avoid software-specific requirements in the supply chain.
- The report metadata captured is not currently sufficient to allow full record keeping for the purposes of a records management system. The administrative tasks of defining retention dates, review and disposal at the (report) record level in particular are not captured, requiring manual, offline record keeping.
- Currently the factual exploratory hole data submitted in AGS data format by the supply chain is not able to be examined and visualised by the Geotechnical Advisors in Highways England, due to a lack of provision of the correct software and training amongst staff. At the time of writing there is not a defined need to visualise the data, beyond that presented in the report, however as the supply chain becomes more data-centric and the data starts to replace part of the reporting this requirement is likely to be more important. Highways England should consider investing in the development of browser-based data visualisation tools as there are no commercial off-the-shelf products that currently fulfil these client-centric requirements.

5.9. Review of Desktop Studies - Arup 2008 and 2010

Research was carried out in 2008 and 2010 by Arup, on behalf of Highways England (TTEAR Tasks 376 and 387) to review the requirements and opportunities for "Electronic Transfer of Desk Study Information" within the scope of geotechnical site investigation.

The tasks produced two reports:

- Electronic Transfer of Desk Study Information - Research Report Stages 1-3 (Oct 2008) and
- Electronic Transfer of Desk Study Information - Research Report Phase 2 (July 2010)

The scope as defined in the Oct 2008 report is repeated below:

“Desk Study’ or ‘Preliminary Sources Study’ are the generic names for collation and assessment of information on site characteristics that is available without undertaking physical surveys (topographic, ground investigation etc).

This research work focuses on geotechnical data aspects. In this context a Preliminary Sources Study (PSS) for a highways-related scheme is focussed on collating and communicating information about the site in relation to the proposed construction works. The information compiled in the study is used by multiple parties through the scheme design and development process and onward into the operation and maintenance of the asset.

An integral part of the PSS is the assessment of ground related hazards. These are documented on a risk register, created during the Preliminary Sources Study and this register is then used throughout the subsequent phases of the Scheme to manage the risks posed by geotechnical features; residual risks are passed on to the maintenance processes.

The current format for reporting Preliminary Sources Studies, namely a paper or PDF document, does not lend itself to effective reuse of information in subsequent detailed ground investigation design or risk assessment. Accordingly the focus of the research is to investigate the options for improving the flow of information on ground hazards from desk study to operations.

Currently geotechnical features and hazards are reported in the Preliminary Sources Study Report (PSSR) produced in accordance with HD22/08 (Design Manual for Roads and Bridges, Volume 4 Section 1 Part 2) “Managing Geotechnical Risk”. The data within the PSSR and risk register produced in this document were therefore the main focus for improvement.”

The work considered the content of the PSSR, especially in relation to communication hazards and risks throughout the project. One of the areas to be considered was the format of reporting, discussed in Section 4.1.1 of the October report and presented below:

“Typically the PSSR is presented as a paper report and usually for a major scheme this comprises several volumes.

In recent years the paper document submission has been supplemented by a PDF file of the document provided to the Agency on CD-ROM. The PDF is a replica of the paper document but does have the advantage of simplifying electronic distribution.

However, the paper based format does not allow rapid analysis of the information nor does it promote interrogation or the re-use of the data. To utilise the information contained in a paper PSSR the recipient is probably faced with re-entering the data into their project management or design systems leading to time and resources devoted to reproducing data with the

incumbent risk of transcription errors. Drawings may have to be digitised which requires specialist hardware and software. The digitisation process can be problematic with respect to co-ordinate systems and accuracy.”

The vision from the recommendations of the Oct 2008 report was as follows:

“Data from the geotechnical Preliminary Sources Study Reports (PSSRs) should be received in a more easily transferable format than PDF files.

Data produced at scheme or project level should be held centrally in an ‘intelligent’ format accessible to a wider range of participants.

Data on ‘geotechnical features’ should include the type and nature of the feature, source of information and geographic location. Defined hazards with consequence, risk and mitigation measures are linked to geotechnical features.

Data can be viewed and reported in both geographical and textual formats from a single source. The requirement will be to view and access data in GIS based applications, and present reports, for example a traditional columnar format risk register.

The information on geotechnical features and risks posed is updated as a project progresses through design and construction. Residual risks at the end of construction are then passed over to operation and maintenance activities.”

The 2010 follow-on report focussed on items 2, 3 and 5 in the above list. Looking at hazards and risks. Additionally the report considered Geotechnical Report Metadata to communicate hazards and risks.

The recommendations from the 2010 report were:

“Integrating existing 3rd party databases ...there are a number of national databases available that would facilitate the mapping of geohazards affecting the HA network. The primary source for these is the BGS¹⁴. Presently the BGS data is only obtained on a project specific basis which means that much of the value of this data for long term maintenance decisions is lost.

The Highways Agency should consider obtaining these databases centrally for improved linkage between geohazards and asset management decisions. However, there are licensing and information copyright issues with placing these databases on a central asset management system, and a more detailed assessment of these issues and costs should be undertaken.

***Residual Geotechnical Risk information** from Geotechnical Features Plans does not present the full picture, since many of these hazards may have been mitigated by construction activities.*

For asset management purposes, residual risks after construction are more relevant, and should be clearly communicated beyond the end of a project.

Final risk registers (as part of the Geotechnical Feedback report) should be uploaded separately in HAGDMS to enable easy access to information on residual risks.

¹⁴ British Geological Survey

Improved classification of new reports When new reports are uploaded to HAGDMS it is recommended that some additional metadata be requested from the report authors via the upload form.

Metadata tags attached to the documents would then allow the presence of geohazards to be flagged and easily identified.

Transfer of existing data It is recognised that the bulk of useful information about geohazards affecting the Highways Agency roads will actually be historical. This information is available but not easily searched or accessed in HAGDMS.

A first step to making this data easier to find would be to digitise reports and introduce a key word searching functionality, such that reports documenting particular hazards would be easier to find. Digitisation of reports via OCR is underway at the time of writing this report.

When all reports are available digitally, they should be searched for all geohazards in the checklist (including synonyms), and this metadata be stored in the report details in the same way as for new reports.

Develop structured links with asset management decisions Once geohazards information is directly accessible and visible in HAGDMS it would be possible to develop structured decision making tools that would prioritise geohazards in terms of their potential to cause unforeseen damage to assets, and align this information with the risk based classification of assets under development, such that assets with highest consequence that are also in areas of significant hazard potential could be flagged up for asset managers."

Discussion

The vision set out in the above reports is still relevant. The current status of the headline recommendations is provided below:

"Integrating existing 3rd party databases"

3rd party data set mapping has been included in HAGDMS where practical. This has been of particular use to the Smart Motorways Programme. There have however been procurement problems, which need to be resolved if the data is to be held in the long term.

"Residual Geotechnical Risk information"

The presentation of final risk registers has not been embedded in processes. There is a current re-write of HD22/08, which is the ideal opportunity to include details of how the final risk registers should be presented and stored. It should however be noted that information that is stored as structured data against an asset is more visible than if it's contained within a report.

"Improved classification of new reports"

The classification of reports using keywords to flag hazard types has been included on HAGDMS. The requirement for the user to populate the keywords should be incorporated into the revision of HD22/08, but it should be made generic to allow for future keywords.

"Transfer of existing data"

The task included an extract of keywords and values from the structured although the task of extracting key words from the reports has only partially been completed.

"Develop structured links with asset management decisions"

This work has not been progressed. Highways England is in the process of creating a risk-based framework for asset management, including value management. Once this work has been finalised it may be possible to develop the structured links. Up to that point the hazard and risk information that exists should be used e.g. for risk-based inspection scheduling.

"Data from the geotechnical Preliminary Sources Study Reports (PSSRs) should be received in a more easily transferable format than PDF files."

The format of PSSRs (and other geotechnical reports) has remained the same. This is partly due to the requirement to have PDF-format records. The aim of enabling a transfer format for desk study information is still current. The technology to enable the transfer of data has become more available since 2010 (see Section 6.5).

"Data can be viewed and reported in both geographical and textual formats from a single source. The requirement will be to view and access data in GIS based applications, and present reports, for example a traditional columnar format risk register."

Following the work looking at desk study information and how it is communicated there has been activity, managed centrally by Highways England to identify and process data and present that information on HAGDMS as structured data and as mapping layers. This work is ongoing and will assist with identifying risks as required.

What has not happened is the ability to transfer the information used to create a PSSR in a smarter way, such that the data does not have to be re-keyed, or re-purchased. The advances in technology (HTML5, JavaScript and GeoJSON) outlined in Section 6.5 of this report provide a way for the data to be shared without creating new systems for viewing, and have overcome some of the limitations of the "old standard" GIS interchange formats.

The use of GeoJSON to transfer spatial data provides a web-friendly format that was not possible with ESRI shape files. Also, the use of browser-based mapping enables the transfer of an interactive map throughout the project, without the users having to install specialist software.

However, there are technical limitations of storage and representation of this data in the current geotechnical asset information system, which cannot be overcome. The design of a replacement system should consider the consumption and representation of the digital PSSR information.

The technology allows (but has not been implemented yet) important information such as hazard/risk maps to be served via a Web Mapping Service (WMS) from Highways England to its supply chain. This will enable the information to be shared more efficiently with project-level GIS systems. Effectively Highways England should mirror what BGS, The Environment Agency and the Coal Authority do, by sharing information. This can be done on a restricted basis if required.

5.10. Data Quality Assessment

A data quality assessment of the geotechnical inventory data and associated processes was carried out in summer 2017 as part of a cross-asset data quality review.

The assessment was carried out against:

- a data extract vs the data requirements set out in the Asset Data Management Manual V5
- the information contained in HAGDMS vs the real world and
- data management processes vs an ISO 55000 maturity model.

The assessment reported in October 2017 and used an alpha-numeric scoring for the Asset Information Quality Indicator. The findings showed that the Indicator was "C3".

This is broken down as follows:

The Process score was "C", which equates to Evidence of processes, but not documented.

A	Documented processes in line with good practice supported by evidence
B	Partially documented processes and/or limited evidence in line with good practice
C	Evidence of processes some of which are aligned with good practice
D	No evidence of coherent processes

Figure 8 Data Quality Process Score

The data profiling and accuracy score was "3", which equates to approximately 90 to 95% accuracy.

Generally this is quite a poor data quality score for a mature system of data management.

The recommendations provided in the report are presented below:

“Geotechnical Inventory Assessment recommendations

The following recommendations are made, based on the results of the data and process quality assessment:

Geotechnical asset information quality is significantly lower in DBFO [Design Build Finance Operate] areas. Although the proportion of the network operated by DBFOs is relatively small, targeting improvements in these areas could result in a disproportionate increase in geotechnical asset information quality. This could be facilitated by modifying contracts that require DBFOs to store geotechnical data, as per the ADMM.

The quality of geotechnical asset information is limited by its [sic] completeness. Action should be taken to ensure all geotechnical assets are recorded in appropriate systems. If accuracy remains the same, this will increase the quality of geotechnical asset information

Improvements to the management of geotechnical data is required to align with good practice. In particular, improvements to assurance (formalising the governance of asset information management activities & improvement initiatives) and capability/training (embedding asset knowledge in our people) will bring about the improved management of geotechnical data.

Information Quality Approach recommendations

The following recommendations could improve the data quality assessment itself:

Although we set out to assess attributes including height, width and angle, these could not be tested with the existing methodology. Future assessments should consider the value / feasibility of alternative methodologies for assessing these attributes

This assessment found significantly different results for DBFO and non-DBFO areas. Future assessments should consider process tests targeted at DBFO areas. In addition, future assessments should consider increasing the sample size for DBFO areas, providing greater confidence in results.”

Regarding DBFOs, the policy of including DBFOs in the data quality and performance reporting processes should be made clear. If DBFOs are to be included it will require high-level policy changes and contractual variations to ensure that the data is captured. Alternatively the data could be captured by Highways England, independent of contractual obligations.

The completeness of assets should be reviewed. There may be problems in the definition of the assets combined with the data quality assessment process, but there is also a known issue of incomplete network definition on the asset information system that needs to be addressed.

The low score of the data governance assessment is surprising. It is recommended that this assessment be repeated taking into account the impact of the renewed governance and updates of the Asset Data Management Manual.

Items that stand out in the data governance assessment that do need to be dealt with are:

- **Training** - Whilst training is provided, records of training are not available. They should be held centrally.
- **Documentation** - Whilst documentation exists it is not managed effectively in terms of periodic review and updates. It is recommended that a geotechnical-specific data management plan be established to co-ordinate and document these governance processes.

However, the scope of the data quality assessment was very broad and did not target specific processes for reporting e.g. Performance Reporting. It is recommended that specific targets for data quality reporting be established and further data quality checks undertaken. The starting point for this should be the information contained in the geotechnical asset information monthly report.

It is recommended that data quality processes and schedules be documented, and results recorded to show the level of data quality vs time.

Data Primacy

Following the data quality review an assessment of the primacy of the asset data systems was undertaken. The key findings of the work are presented below:

- *Most areas store data relating to a single asset, in more than one Asset Information system*
- *The ADMM is well known, received and used*
- *Delay in launch of IAM-IS has led to work-arounds and parallel running*
- *Legacy Asset Information systems are heavily used and unmaintained due to IAM-IS uncertainty*
- *A lot of data is collected and entered manually*
- *Asset Information users are reliant on outdated technology*
- *Lack of formalised quality assurance*
- *Difficulties with reporting tools and idiosyncratic data extraction have caused frustration*

The work provided a table of data primacy against each managing area, or groups of areas. The table, or tracker is presented in Figure 9. Note at the time of writing it has draft status.

Area	Asset class	Asset data category	System type	System name
1&2	Geotechnical	Construction	Prime	HAGDMS
1&2	Geotechnical	Inventory	Prime	HAGDMS
1&2	Geotechnical	Renewal / Maintenance / Operational	Prime	HAGDMS
1&2	Geotechnical	Condition	Prime	HAGDMS
3	Geotechnical	Construction		
3	Geotechnical	Inventory		
3	Geotechnical	Renewal / Maintenance / Operational		
3	Geotechnical	Condition		
4	Geotechnical	Construction	Prime	HAGDMS
4	Geotechnical	Inventory	Prime	HAGDMS
4	Geotechnical	Renewal / Maintenance / Operational	Prime	HAGDMS
4	Geotechnical	Condition	Prime	HAGDMS
4	Geotechnical	Inventory	Duplicate	IAM-IS
4	Geotechnical	Inventory	Duplicate	ENVIS
6&8	Geotechnical	Construction	Prime	HAGDMS
6&8	Geotechnical	Inventory	Prime	HAGDMS
6&8	Geotechnical	Renewal / Maintenance / Operational	Prime	HAGDMS
6&8	Geotechnical	Condition	Prime	HAGDMS
7	Geotechnical	Construction		
7	Geotechnical	Inventory	Prime	HAGDMS
7	Geotechnical	Renewal / Maintenance / Operational	Prime	HAGDMS
7	Geotechnical	Condition	Prime	HAGDMS
9	Geotechnical	Construction		
9	Geotechnical	Inventory		
9	Geotechnical	Renewal / Maintenance / Operational		
9	Geotechnical	Condition		
10	Geotechnical	Construction		
10	Geotechnical	Inventory	Prime	HAGDMS
10	Geotechnical	Renewal / Maintenance / Operational	Prime	HAGDMS
10	Geotechnical	Condition	Prime	HAGDMS
10	Geotechnical	Inventory	Duplicate	Confirm (area 10)
10	Geotechnical	Renewal / Maintenance / Operational	Duplicate	Confirm (area 10)
10	Geotechnical	Inventory	Duplicate	HAPMS
12	Geotechnical	Construction		
12	Geotechnical	Inventory	Prime	HAGDMS
12	Geotechnical	Renewal / Maintenance / Operational	Prime	HAGDMS
12	Geotechnical	Condition	Prime	Highstone
12	Geotechnical	Condition	Duplicate	HAGDMS
12	Geotechnical	Inventory	Duplicate	IAM-IS
12	Geotechnical	Condition	Duplicate	IAM-IS
12	Geotechnical	Inventory	Duplicate	Highstone
13	Geotechnical	Construction		
13	Geotechnical	Inventory	Prime	HAGDMS
13	Geotechnical	Renewal / Maintenance / Operational	Prime	Confirm (area 13)
13	Geotechnical	Condition	Prime	HAGDMS
14	Geotechnical	Construction		
14	Geotechnical	Inventory	Prime	HAGDMS
14	Geotechnical	Renewal / Maintenance / Operational	Prime	HAGDMS
14	Geotechnical	Condition	Prime	Confirm (area 14)

Figure 9 (Draft) Data primacy tracker for the geotechnical asset information (Feb 2018)

It can be seen that HAGDMS is not designated at the primary system for some information. This should be investigated as soon as possible to understand whether the interview responses weren't correct or if other systems are being used. If other systems do hold primary data, the impact on the reporting and geotechnical asset management processes should be determined. Methods of managing other systems in terms on monthly and performance reporting must be established.

Regarding the other findings of the study, these are the same themes picked up in other parts of this report.

5.11. Geotechnical Data Handback Task Review

A research task "*Handing over geotechnical data*" (SPaTS 1-105) was undertaken by Mott MacDonald in 2017. The objectives of the task were:

"To make more efficient the handover/transfer procedures (including the validation of data) from Delivery Partners to Highways England's Asset Management System,

To set out the processes and procedures that will allow provision of data and information which is directly compatible with the asset inventory data in Highways England asset system,

To set out the processes and procedures that will allow provision of more detailed information to aid future risk and performance assessments, particularly with regard to the identification of ground related hazards, the construction of Special Geotechnical Measures (SGMs) and identification of residual risks.

To put in place processes and procedures that more fully support Highways England's adoption of the UK Government Construction Strategy which requires fully collaborative 3D BIM (with all project and asset information, documentation and data being electronic)."

The task reviewed the requirements contained in the following documents:

- HD41/15 & HD22/08,
- IAN 105/08 & IAN 184/16,
- Asset Data Management Manual,
- BIM UK Government Construction Strategy,
- Data Transfer Format document of AGS,
- BS8574:2014 (Code of Practice for the management of geotechnical data for ground engineering projects) and
- pathfinder activities undertaken for the A30 Bodmin to Indian Queens and A14 Kettering Bypass.

The output from the task includes:

- A documented draft set of processes for handover of geotechnical data from major schemes.
- Associated training materials and training events.
- Documentation of any required changes to Highways England documents e.g. The ADMM, DMRB, IAN 182, HAGDMS user documentation, Model contract clauses etc.

At the time of writing the task had not fully reported.

In some areas, such as recording existing SGMs, free text fields are used, which although not ideal at least allow data to be captured and retrieved.

Feedback from the data preparation stage of the Smart Motorway Programme and day-to-day use of the "Projects" functionality on HAGDMS shows that the inability to assign one report to two or more projects is a distinct limitation.

5.11.1. Future Handover and Handback Requirements

The current handover and handback task output is targeted at what is possible at the time of the task. It is typically a manual process. The HAGDMS system is due to be refreshed in the period 2018-2021 and this will provide opportunity to automate the process if the scope and specification allow.

The scope of the refresh activities should be prepared such that interoperability is at the heart of the software capability.

5.12. Employer's Requirements

Feedback from the interviews conducted as part of this task raised a couple of points for further consideration:

- The ground investigation contractors are not generally informed about Highways England standards. Their direct/indirect contact is via the consulting engineer. Highways England's requirements for the provision of information in the H & S file is not clear.
- Because site investigation may take place without commencement of a major project, which will have the EIR documentation, there is no visibility of the EIR.

It is recommended that EIR documentation be enabled for smaller schemes, including repairs. It will help formalise the reporting and ensure a consistent approach.

5.13. Serviceability and Network Criticality

Risk-based asset management involves an understanding of the restrictions associated with the asset, the interaction between assets, the road network and environmental considerations. These include data sets such as:

- Traffic Counts
- Diversion Routes
- Other assets (including 3rd party assets)
- Capacity
- Hard shoulder running

Some of these data sets are available (e.g. diversion routes), however access to them is not easy, neither is it consistent across maintenance areas.

Development of the data sets is not within the scope of geotechnical asset management, however investigations should be carried out to determine the completeness and accessibility of the data sets, to provide access through the Portal as a minimum. Ideally the data sets should be included as a mapping layer, or in a suitable GIS format to allow spatial analysis to be undertaken.

A cross-asset approach for assessing the criticality of assets on the SRN will be needed to support the development of future metrics (RIS 3) required by the

business to report on performance of its geotechnical assets, see also Section 6.17.

5.14. Whole Life Modelling and costs

Whole life modelling, including deterioration and costs for maintenance/renewals is a large topic that has not currently been tackled effectively in Highways England geotechnical asset management.

Whole life modelling is used to determine the prioritisation of spending to maximise value for money.

- Inputs into a whole life model includes the following:
 - Length of asset (at a certain condition state)
 - construction methods/material types
 - network criticality
 - rate of Deterioration
 - cost of repairs/replacement
 - interaction with other assets and the environment etc.

Currently, geotechnical value management uses information contained in the GeoAMPs, which has been collated using engineering judgement and cost information based on local, similar schemes, where possible.

The use of the GeoAMPs is preferred to a "black box" algorithm. It is easier to understand and justify. However, there is a problem in that the GeoAMPs are distributed as individual PDF files, so the data they contain is not easily extracted for querying and reporting.

It is recommended that a system be established to enable the authors of the GeoAMPs to populate a central system. It is important that this system have appropriate security controls such that confidentiality of cost information is preserved. The system may be a simple file store (populated by uploading CSV/spreadsheet files), or a client/server database. The data structure is relatively simple and consequently would be fairly easy to implement.

When looking at deterioration modelling, it should be noted that the geotechnical asset should not be looked at in isolation. E.g. a large proportion of geotechnical failures is caused by defective drainage.

5.15. Resilience Review

In October 2015, Arup, as part of the Arup/URS Consortium, was commissioned through Highways England Framework for Transport-related Technical and Engineering Advice and Research to undertake TTEAR Task 634 'Resilience of geotechnical assets on the SRN to severe weather events'.

The overall objective for the task was to:

“Develop an improved categorisation of the resilience of Highways England’s geotechnical assets to a range of severe weather events. The demand that these events can impose should be compared to the basis of design of

geotechnical assets and to our understanding of their current condition (including underlying hazards)."

The aim of the categorisation was to:

"ultimately assist Highways England decision makers seeking to understand the potential impact of severe weather events forecast in the short term and long term climate change on geotechnical assets and consequently on the SRN."

The output from the task was entitled [Resilience of geotechnical assets on the Strategic Road Network to severe weather events, Phase 2 – Final report; June 2016.](#)

The report presented a resilience framework focused on *"identifying and prioritising 'vulnerable' geotechnical assets"* and the aim of the resilience framework was:

"to allow Highways England to prioritise those geotechnical assets which present the highest risk due to severe weather events and therefore require appropriate and proportionate resilience measures. For example, the framework could be used to inform reactive responses when severe weather is forecast or for planning pro-active interventions."

The executive summary includes the following text indicating that there are data limitations, which prevent a detailed model from being formulated:

"Due to the current available information the proposed framework is based on a simple model approach and the focus is on the vulnerability assessment (Step 2) for specific severe weather types. It has been concluded that categorisation of all geotechnical assets in terms of their resilience is not currently possible, pending additional data being available within HAGDMS about ground-related hazards, and special geotechnical measures. Therefore at this stage, only an approach to categorising assets is presented, an actual categorisation is not yet done."

Section 6 'Recommendations for further work' includes recommendations for improved information to support the resilience work. Two recommendations are relevant to geotechnical asset information:

6.1.6 Improve asset data knowledge

A number of recommendations regarding asset knowledge and condition have been suggested as a result of this reports progression. These are detailed below:

Drainage – Drainage plays a key role in maintaining a geotechnical assets integrity (e.g. Preliminary results from Task 434, Mott Macdonald). However, drainage asset condition and knowledge is currently limited for the SRN.

Special geotechnical measures – A parallel task has been ongoing to establish the type and location of special geotechnical measures on the SRN. Once this information is available on HA GDMS, this can be incorporated into the assessment. Further work may then consider the impact of severe weather events on the deterioration of such special measures, which over time may result in an increased vulnerability of a geotechnical asset, considering their long design lives.

Flood risk mapping – the outputs of Task 433 have at the time of writing, gone live on HA GDMS. Comprehensive flood risk maps will require incorporation into the resilience assessment framework described in this report.

6.1.7 Integration of HA WIS with HA GDMS

The resilience framework presented in this report relies upon combining information about weather events, sourced from HA WIS, with geotechnical data contained within HA GDMS. Currently, these are distinctly separate processes within Highways England and more information is required as to the capabilities of HA WIS in respect of the resilience framework presented.

Ultimately, further integration and use of network weather data to inform vulnerability and subsequent risk analysis of geotechnical assets would be sought. The forthcoming IAM IS system may work towards this aim, and Figure 23: provides a potential GIS architecture for such an integration in terms of severe weather management.”

A subsequent task awarded under SPaTS 1-085 ‘Geotechnical resilience enhancement measures’ has looked at understanding and benchmarking Highways England’s severe weather management processes and the concept of geotechnical ‘vulnerable locations’. Outputs from the task included a series of guidance notes to provide non-specialists dealing with the presence of ground related hazards with robust and consistent information to inform their decisions and seek advice as appropriate.

Discussion

The recommendations regarding special geotechnical measures has been implemented to a certain degree, however there is more work to do. This is covered in Section 5.6.

Regarding linking HA WIS with HAGDMS, this may be possible once the HAGDMS system refresh has been accomplished in 2020/2021. Discussions regarding interoperability should be made with the Highways England Project Sponsor at an appropriate point in time.

5.16. Hazard Task Review

The primary output of the Hazard Task was a hazard map. This has been included on HAGDMS as a mapping layer. The requirements for any associated structured data should be reviewed and included as part of any configuration or software development tasks.

At the time of writing work was being commissioned to consider asset vulnerability so the data requirements were not well established. However, it is likely that a vulnerability score or index will be required, either at network and/or asset level. In addition, it is likely that causes and mitigations will need to be recorded as structured data.

A vulnerability map may be produced as a deliverable, which may be hosted on HAGDMS. The output from the task should be reviewed in the light of any development of the asset information system (IAM IS or HAGDMS).

5.17. Geotechnical Performance Indicators

At the time of writing proposals for the revised condition geotechnical indicator were being prepared for agreement with the ORR (March 2018). The revised Performance Indicator is due to be validated in 2018-2020 and rolled out in March 2020.

An assessment of the data requirements for the geotechnical indicator show that there is a problem with the attribution of the observations with respect to the type of road (i.e. main carriageway, off slip etc.) This problem manifests itself as the inability to compare the HAPMS (Highway Agency Pavement Management System) main carriageway length with the HAGDMS main carriageway length. This is required in order to determine the length of the true asset length compared to the inspected asset length.

It is very likely that the inaccuracy of the data is due to the fact that until now it has not been actively used, just collected. At the time of writing the road type attribution was being cleaned up, however, there will need to be future quality controls to ensure that this attribute is populated accurately. The attribute will need to be included in a quality check as part of the system for Geotechnical Performance Indicator reporting.

The start and end co-ordinates of observations and earthworks should be reviewed as part of a data quality assessment to ensure that observation and earthworks lengths are reported correctly. Associated data quality assessments are included in Section 5.11.

There is an identified business requirement to develop risk/serviceability (leading) indicators to report on the performance of the geotechnical assets in RIS3. Proposals for the development future indicators will be put forward by end of 2018. Future indicators will require establishment of measures of criticality (cross-asset) and deterioration that are currently not established in the business, also Sections 6.13 and 6.14. Timescale for development of these measures should align with business requirements on performance reporting.

6. Review of external initiatives

6.1. Introduction

A review of initiatives that Highways England does not have complete control over (even though they may have provided some funding in the past) was carried out to look at the wider influences in the production and use of geotechnical information. These mainly focussed on:

- the increasing use of BIM (Building Information Modelling),
- data formats and
- emerging technology.

The topics are discussed further in the following sections.

6.2. High level BIM and digital construction initiatives in the UK

In 2011 the **Government Construction Strategy** (Cabinet Office, 2011) announced the Government's intention to require collaborative 3D BIM, with all project and asset information, documentation and data being electronic, on its projects by 2016. This is commonly known as 'Level 2' BIM.

The UK **BIM Task Group** was formed, bringing together expertise from industry, government, public sector, institutes and academia. This group received Government funding which was used on a number of initiatives, including development of COBie, PAS1192 parts 2 and 3, and the NBS BIM toolkit. Approaching the 2016 deadline, the original BIM Task Group activity wound down and it has been effectively replaced by two new entities as follows.

The **UK BIM Alliance**, officially launched in October 2016 with the objective of leading the adoption & implementation of BIM Level 2 on both public and private sector projects. This is now an industry led organisation with no Government funding. In October 2017 it was announced that UK BIM Alliance and the UK & Ireland chapter of buildingSMART (discussed further in the next section) had agreed to merge.

Also in October 2016 it was announced that Innovate UK and the Department of Business Energy and Industrial Strategy had formed a partnership to deliver through **Digital Built Britain**, the next phase of digitisation in the construction sector. In November 2017 the Government confirmed funding to enable the launch the **Centre for Digital Built Britain**, a partnership between the Department of Business, Energy & Industrial Strategy and the University of Cambridge. This will continue the work of Digital Built Britain and the BIM Task Group including the development of Level 3 BIM as described in *Digital Built Britain - Level 3 Building Information Modelling – Strategic Plan* (HM Government, 2015).

A number of voluntary specialist interest groups were established or brought together under the 'BIM 4' brand by the BIM task Group. These now fall under the remit of the UK BIM Alliance. Two are these are especially relevant to Highways England: BIM 4 Infrastructure and BIM 4 Highways.

BIM 4 Infrastructure (UK), or 'BIM4IUK' for short, is a Special Interest Group (within the Association of Geographic Information (AGI) which is also supported by the Institution of Civil Engineers (ICE) and the Construction Project (CPI) Committee. **BIM 4 Highways** was formally launched in February 2017. Highways England are understood to be involved with David Owens amongst the presenters at the launch event.

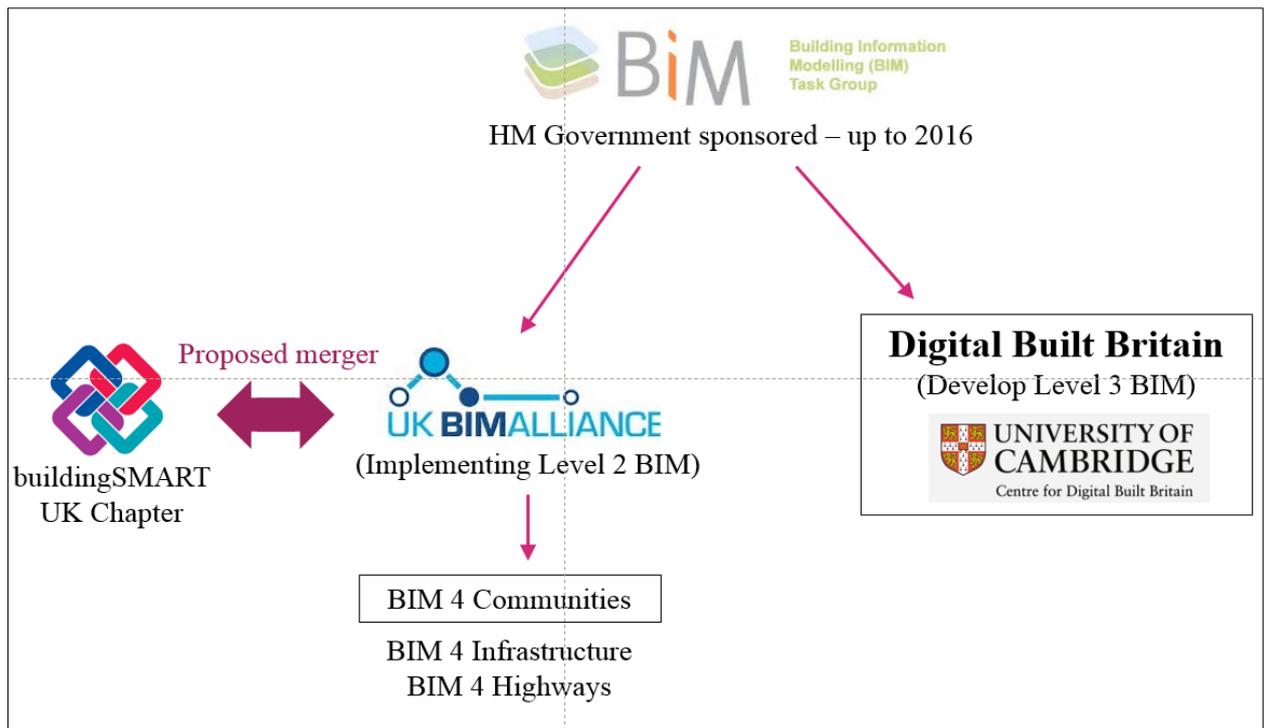


Figure 10 Relationship of UK BIM organisations

A relevant recent report is the **ICE State of the Nation 2017: Digital Transformation** (ICE, 2017). This report focuses on infrastructure, including both digital delivery and smart infrastructure. In the summary it exhorts: “Now is the time to align Government initiatives with a renewed, coordinated commitment from industry to capitalise on the benefits digital transformation can bring to the productivity and resilience of our infrastructure services.”

The above documents and organisations promote a general direction of travel towards BIM and digital technologies. It is recommended that Highways England should keep track of and, where appropriate, participate, e.g. taking a lead in the relevant BIM 4 groups, or offering support to UK BIM Alliance. By doing so Highways England will have opportunities to ensure that UK BIM practice evolves in a manner compatible with its needs. Geotechnical matters are only a small part of the BIM picture and any such support would best be led from the BIM/AIG team within Highways England.

Useful links:

- HM Government Construction Strategy 2011: <https://www.gov.uk/government/publications/government-construction-strategy>
- BIM Task Group: <http://www.bimtaskgroup.org/>
- UK BIM Alliance <http://www.ukbimalliance.org/>
- Digital Built Britain report: <http://www.digital-built-britain.com/>
- BIM4Infrastructure: <http://www.bimtaskgroup.org/bim-4-infrastructure-uk/>
- ICE State of Nation report: <https://www.ice.org.uk/media-and-policy/policy/state-of-the-nation-2017-digital-transformation>

6.3. Specific BIM initiatives relevant to Highways England

6.3.1. buildingSMART and IFC

buildingSMART is an established (since 1995) industry led international organisation whose mission can be summarised as:

- Delivery of ‘open’ standards to enable and assist effective implementation of BIM
- Identification and dissemination of improved processes relating to BIM



Its members are drawn from academia and industry, with the latter from client bodies, designers and contractors. Academia and design appear to be most strongly represented. Funding comes partly from members but also from client bodies with an interest in the outcomes. Much of the work done is as work ‘in kind’ by participating organisations.

buildingSMART is divided up into international ‘chapters’ plus the parent organisation ‘buildingSMART International’ (bSI). These are divided up into several ‘rooms’ covering different aspects of bSI’s work. The ‘Infraroom’ covering infrastructure applications would be of most relevance to Highways England. There is a UK (and Ireland) chapter, which is headed by Anne Kemp of Atkins. As noted earlier, this chapter plans to merge with UK BIM Alliance.

buildingSMART has developed **Industry Foundation Classes (IFC)** which is an open standard for structuring the data of the built environment. The IFC model specification is open and available, and is an official International Standard ISO 16739:2013 (ISO, 2013).

The continuing development of IFC is referenced in *Digital Built Britain* which includes specific references to “Geotechnics IFC” and “Infrastructure IFC” (HM Government, 2015, pp. 22).

IFC is an open standards based (software neutral) data schema for sharing construction and facility/asset management data across various applications. It is an object-oriented data schema based on class definitions representing the objects (such as building elements, spaces, properties, shapes, etc.) that are used by different software applications used in construction or facility management project.

In practice, it is not intended that every IFC exchange includes whole schema as this could lead to large files with much superfluous data. buildingSMART have also created the concept of Model View Definitions (MVD) which define a subset of the schema for exchange. A small number of MVDs have been developed to date. MVDs could limit exchange to, for example, views specific to analysis, design, co-ordination or facility/asset management. COBie can be considered to be a MVD.

Also relevant is the buildingSMART Data Dictionary (bSDD) which is a library of objects and their attributes. It is used to identify objects in the built environment and their specific properties regardless of language, so that “door” means the same thing in Iceland as it does in India. It does this by assigning a global unique ID to each defined property of each defined object.

IFC is a commonly used format for exchanging models to facilitate collaboration in Building information modelling (BIM) based projects, primarily in the buildings sector. Even in this sector, shortcomings in the specification and, perhaps more

significantly, its implementation in software, mean that it is not used a commonly as desired or intended, with much collaboration still based on exchange via proprietary software file formats, i.e. native files from modelling software.

At present it is less commonly used in the infrastructure sector. In part this may be due to less demand for the exchange of model information between disciplines compared to the buildings sector. Another major factor is that the data schema is less well developed for infrastructure applications. However, there is now a major focus on infrastructure application led by the buildingSMART Infraroom.

A recent enabling development is IFC Alignment which allows geometry to be referenced from an alignment string, which is vital for linear infrastructure projects. A standard is now in place but it is not yet fully implemented in mainstream software.

Other recent, ongoing or imminent work relevant to infrastructure includes:

- A report titled 'Infrastructure Asset Managers BIM Requirements' has been produced by the Infraroom (lead author: Phil Jackson). At the time of writing it was going through an approval process, with a view to being published in early 2018.
- Infrastructure Overall Architecture Project: in March 2017 a document was published (buildingSMART, 2017) providing an overview of existing, new and proposed extensions to the IFC schema for modelling infrastructure. The intent of this document is to ensure that IFC Road, IFC Rail and IFC Bridge are developed in a consistent and compatible way.
- Following on from the above, the Common Schema Project will coordinate role across the concurrent linear infrastructure projects, providing guidance and technical advice to ensure schema consistency and harmonisation on concepts that are common to more than one domain. For example, earthworks and drainage are common to IFC Road and IFC Rail, and ground investigation and ground models are relevant to all domains. As of November 2017, this is a planned project seeking final approval and funding.
- IFC Road will extend the IFC schema to cover highway infrastructure. It will build on work carried out by the Korean Institute of Construction Technology who have already developed a full schema which has been issued as a buildingSMART 'SPEC' document, which is a publicly available specification for comment. As of November 2017, this is a planned project seeking final approval.
- IFC Rail will extend the IFC schema to railway infrastructure, inclusive of all relevant systems. This will build on a schema developed by China Rail, which has been issued as a SPEC.
- IFC Bridge, which should cover all types of bridge structure, is being worked on in a French led initiative.
- IFC Ports and Harbours is a new project that will extend the schema into the maritime domain.
- IFC Tunnel is a relatively new proposal but it is struggling to progress due to lacking of funding at present.

The Common Schema, IFC Road and other schema extension projects are currently started or about to start, subject to bSI internal approval procedures. They are aiming to complete within a period of two years to feed in to the release of IFC5 standard, proposed for 2020. The early phases of these projects, generally aiming to completing by mid-2018, will include definition of requirements (for the schema), identification of use cases and input to the Common Schema project.

Useful links:

- buildingSMART home page: <http://www.buildingsmart.org/>
- bSI call for participation: <http://www.buildingsmart.org/international-infrastructure-standard-call-for-participation/>
- bSI Infraroom: <http://www.buildingsmart.org/standards/rooms-and-groups/infrastructure-room/>
- bSI reports and standards: <http://www.buildingsmart.org/standards/standards-tools-services/>
- Article on COINS and COBie: <https://www.ice.org.uk/knowledge-and-resources/information-sheet/what-are-coins-and-cobie-and-how-can-they-be-used>

Discussion and recommendations for buildingSMART and IFC

IFC can provide an open standards based software neutral format for viewing, exchange and storage of design and construction details of Highways England infrastructure, i.e. replacing or supplementing drawings and/or models currently viewed, stored and exchanged via proprietary software formats. Most modelling software is already capable of IFC import and export. IFC files can be read directly and there are several IFC viewers available on the market, including freeware. Some information management software, e.g. Asite, already has IFC viewing capability built in. Furthermore, IFC used in conjunction with MVD could allow different 'views' of the model to be specified, e.g. an asset management view could be generated if required.

IFC is well established in the building domain. Its development and use for infrastructure is promoted in the *Digital Built Britain* publication. Given its origins and widespread worldwide use, it is likely that it will remain supported by software in the future. It should certainly be considered more future proof than proprietary formats.

Particular interoperability benefits that should arise from use of IFC within Highways England are:

- On projects, use of an established standard software neutral transfer format will allow suppliers to collaborate more efficiently whilst still using their preferred authoring software.
- In legacy/archive use, having model data in this relatively common and future proof format should make it easier for future users to view or access models, whatever software they happen to be using at the time.

A review of some data transfer formats in a Highways England context been published online, based on work done for Highways England by Atkins in 2015 (Woods, 2016). This included a recommendation relating to IFC as follows:

“The supply chain and software vendors should be encouraged to make means to supply the geometric content in the open-standards IFC format, together with the original proprietary formats as permitted by IAN184. At minimum, the resulting structure must be able to hold the bounding shape and the unique ID for each asset (tools such as Navisworks already convert 3D solids to BREP equivalents of their surface – so this is not a major software challenge). Ideally far more intelligence would remain in the data structure including the alignment geometry. Adopting open formats is a key part of BIM Level 3 and is relevant to any transfer mechanism.”

Therefore the following are recommended:

- Encourage use of IFC for collaboration on projects, e.g. handover of model to other designer, or contractor, as IFC.
- Require handover of full detailed model as IFC at end of project for archive purposes

The above should be considered to be long term aspirations that are dependent on successful development of the IFC schema for infrastructure. It is recommended that Highways England work with buildingSMART on this development with particular focus on schema for:

- earthworks and other geotechnical assets: part of IFC Road / Common Schema Project, in progress or starting up
- ground investigation: already identified as of interest to IFC Bridge and IFC Tunnel, and likely to be considered as part of Common Schema Project as it is relevant to all IFC domains; interface with the AGS Format (for ground investigation) needs to be considered
- ground models: already identified as of interest to IFC Ports and Harbours and IFC Tunnel, and likely to be considered as part of Common Schema Project as it is relevant to all IFC domains
- In addition, Highways England should also consider developing a Model View Definition for IFC that can create Highways England asset management subset of model, e.g. for input to HAGDMS

Within Highways England, there is understood to be little current engagement with buildingSMART or about IFC. However, based on recent discussions with others within Highways England looking at BIM and asset data initiatives, there was a consensus that Highways England should become more engaged with the development of IFC. This engagement should be much wider than only the geotechnical domain with IFC Bridge and IFC Road particularly relevant to other disciplines within Highways England.

buildingSMART is currently keen to engage with infrastructure asset owners, to obtain both expertise and funding. A number of transportation infrastructure agencies are involved via sponsorship or membership, but the UK is currently poorly represented.

If there is to be such engagement from Highways England then it is important that this is initiated quickly given the current status of the bSI Infraroom project described above. Schema requirements for the IFC Road and Common Schema projects are currently being developed and expert panel reviews, which Highways England could potentially participate in, are expected to take place in the early part of 2018.

It is understood that IFC and buildingSMART could fall within the remit of SPaTS task 1-395 Building Information Modelling (BIM) Level 2 Embedment. It is suggested that Highways England geotechnics provides input to this task to ensure that the recommendation included here are taken forward.

6.3.2. Uniclass 2015

Uniclass 2015 is a unified classification for the UK covering all construction sectors. Originally released in 1997, Uniclass allows project information to be structured to a recognised standard. This original version has now been heavily revised, to make it more suitable for use with modern construction industry practice, and to make it compatible with BIM now and in the future.

Development of Uniclass 2015 has been led by the National Building Specification (NBS) as part of the NBS BIM Toolkit project, which was funded as part of UK Government investment in BIM Level 2. Uniclass is considered to be dynamic with NBS continuing to maintain and update it until at least 2020.

Uniclass 2015 is not the only available classification system in the world with Omniclass one of the alternatives extensively used in North America. However, after a review, NBS decided the best solution for the UK was to continue to develop Uniclass as the leading UK system.

In brief, Uniclass 2015 provides:

- A unified classification system for the construction industry
- A hierarchical suite of tables that support classification from, e.g., a road network to a kerb unit.
- A numbering system that is flexible enough to accommodate future classification requirements
- A system compliant with ISO 12006-2 'Building construction – Organization of information about construction works – Part 2' (ISO, 2015) that supports mapping to other classification systems in the future

In addition to providing a classification system to physical objects, Uniclass 2015 also includes for spaces/locations, activities (e.g. use of asset) and information deliverables (e.g. ground investigation report).

An Application Programming Interface (API) is available for Uniclass allowing the system to be easily incorporated into third party software.

In practice, Uniclass has application during design, construction and asset management. For the latter, searching by Uniclass code would allow particular systems or products to be quickly identified. Whilst this may already be possible to a degree, adopting a national system provides the following additional benefits:

- Supply chain would be using a system that they are probably already using, i.e. for other infrastructure clients or in the building sector.

- Facilitates easier sharing of information resources between infrastructure owners.

Highways England are considered to be a key stakeholder in the development of Uniclass. Some work has already been done on mapping the Highways England ADMM to Uniclass.

It is recommended that Highways England actively participates in the further development of Uniclass 2015 to ensure that it is closely aligned with Highways England asset management requirements. A priority for consideration is earthworks classification systems (Uniclass code Ss_15). In addition, Highways England should focus on improving the current classification relating to ground investigations (Ac_15_75) and ground investigation reporting (PM_20_20).

Useful links:

Uniclass 2015: <https://www.thenbs.com/services/our-tools/introducing-uniclass-2015>

6.3.3. Geospatial led initiatives (InfraGML)



The **Open Geospatial Consortium (OGC)** is an international consortium of more than 525 companies, government agencies, research organizations, and universities participating in a consensus process to develop publicly available geospatial standards.

Geography Markup Language (GML) is an XML (eXtensible Mark-up Language) grammar defined by the OGC to express geographical features. GML serves as a modelling language for geographic systems as well as an open interchange format for geographic transactions on the Internet.

The most well-known application of GML is CityGML which is an open standardised data model and exchange format to store digital 3D models of cities and landscapes. It is implemented as an application schema for GML3, and it is an official international standards of the OGC. However it is optimised for cities, not linear infrastructure.

LandXML is a non-proprietary XML data file format containing civil engineering and survey measurement data commonly used in the Land Development and Transportation Industries. The LandXML user community consists of over 650 organizations with 750 members in over 40 countries and the standard is supported by over 70 registered software products.

LandXML is not compliant with GML, and previous attempts to make it so have failed. It is not supported by a recognised international standards organisation. To address this, OGC have developed a new candidate standard called InfraGML. This provides a use case driven subset of LandXML functionality, but implemented with GML and supported by a UML (Unified Modelling Language) conceptual model.

The UML Conceptual Model, **LandInfra**, was developed by the OGC in cooperation with buildingSMART International (bSI) and was approved as an OGC standard in August, 2016. It is divided into six parts as listed:

- Part 0: LandInfra Core Encoding Standard
- Part 1: LandInfra Land Features Encoding Standard
- Part 2: LandInfra Facilities and Projects Encoding Standard
- Part 3: LandInfra Alignments Encoding Standard
- Part 4: LandInfra Roads Encoding Standard
- Part 5: LandInfra Railways Encoding Standard
- Part 6: LandInfra Survey Encoding Standard

A draft candidate standard for **InfraGML** was issued in January 2017 (Open Geospatial Consortium, 2016). The comments period closed March 2017.

InfraGML should, as it develops, provide a schema optimised for linear infrastructure that may be of use and interest to Highways England or those working on Highways England projects in the geospatial, i.e. GIS, domain. It may also, in time, render LandXML obsolete. It is likely that IFC and InfraGML will coexist with different target users, the former aligned to BIM and the latter to GIS. However, buildingSMART and OGC are working together to ensure their work is complementary. For example, IFC Alignment and the implementation of alignments in InfraGML are based on the same conceptual model.

Given the close relationship between buildingSMART and OGC, it is suggested that Highways England concentrate their attention on the former rather than seek to engage with OGC directly.

Useful links:

- OGC: <http://www.opengeospatial.org>
- LandXML: <http://www.landxml.org/>
- UML: <http://www.uml.org/index.htm>
- LandInfra conceptual model: <http://www.opengeospatial.org/standards/landinfra>
- InfraGML schema: https://portal.opengeospatial.org/files/?artifact_id=72352

6.3.4. Other general BIM or asset management related initiatives

The **Infrastructure Asset Dictionary for the UK (IADD4UK)** is an initiative that was supported by the (former) UK BIM Task Group. Its aim is to provide a common asset data dictionary suitable for all UK infrastructure assets supported by a common Asset Data Dictionary Documents (AD4). A brief presentation document is available online which shows examples of AD4 documents produced by Crossrail. The intent was to cover road, rail power and water infrastructure. However, it is understood that the leader of this project has stood down and the project is currently without a leader and funding. Therefore it is recommended that Highways England liaise directly with other infrastructure owners regarding alignment of asset data dictionaries.

COINS (Construction Objects and the Integration of processes and Systems) is a software framework to manage the storage, transmittal and update of BIM data throughout a supply chain. COINS was specifically developed for the Dutch BIM community and documentation has been published by the Dutch government Standardisation Forum as open resources (COINS, 2016).

COBie (Construction Operations Building Information Exchange) is an international standard relating to managed asset information including space and equipment.

COBie helps capture and record important project data at the point of origin, including equipment lists, product data sheets, warranties, spare parts lists, and preventive maintenance schedules. In September 2014, a code of practice for COBie was issued: BS 1192-4:2014 (BSI, 2014).

As with IFC, the origins of COBie in the UK are in the buildings sector. The schema is buildings biased but can be interpreted for infrastructure. COBie is most commonly exchanged in spreadsheet format, but other transfer mechanisms are possible, including IFC. buildingSMART have published an IFC Model View Definition which equates to COBie.

A review of COINS and COBie in a Highways England context been published online, based on work done for Highways England by Atkins in 2015 (Woods, 2016). The conclusions included a recommendation for trial of COINS, but it is assumed that this was not pursued. Based on the further work done for this report, there is considered to be little merit in undertaking a trial of COINS.

The same report also concluded that COBie was not well suited to Highways England requirements. It is suggested that work on Highways England's own data dictionary should take precedence as there does not appear to be much support for COBie in the infrastructure domain right now. Based on the further work done for this report, this conclusion remains unchanged.

Useful links:

- COINS and COBie article/paper: <https://www.ice.org.uk/knowledge-and-resources/information-sheet/what-are-coins-and-cobie-and-how-can-they-be-used>
- COBie MVD: http://docs.buildingsmartalliance.org/MVD_COBIE/

6.4. Geotechnics-focused groups and initiatives

6.4.1. BIM for the subsurface

BIM for the subsurface is a recently completed research project funded by Innovate UK under its Digitising the Construction Industry initiative. The project team comprised the British Geological Survey (BGS), Atkins, Keynetix and Autodesk.

The project had three elements:

- Access to data, e.g. from BGS National Archive
- Hosted Cloud Services
- 3D modelling

The main output from the Access to data element is set of tools allowing BGS datasets to be purchased directly from proprietary software. The datasets include BGS mapping data and AGS data from ground investigations. The AGS data is generated from a BGS 'agnostic' database which is understood to deal with most of the inconsistencies that arise from 'as received' AGS files, e.g. inconsistent use of codes and spatial referencing. A system for uploading data is also available. At the time of writing, these systems are being beta tested with a full launch planned by September 2017.

Whilst the system developed here can only be accessed through the proprietary software at present, the intent is for the BGS data to be made available for other software developers.

For 3D modelling, the project team concluded that concerns about uncertainty in modelling, and liability, were such that they could not recommend sharing of truly 3D ground models represented by surface or volumes. In conjunction with BGS, the project instead concentrated on use of 3D fence diagrams, i.e. planes joining the individual boreholes. The project included the development of a simple to use interface within CAD allowing easy import, export and modification of such fence diagrams.

The output from this completed project, when disseminated properly, may be of interest and use to those in the Highways England supply chain. The approach to ground modelling, using fence diagrams, is surprising as the use of surfaces for defining 3D ground models is already widespread, and is likely to continue.

6.4.2. AGS Data Format Working Group



The **Association of Geotechnical and Geoenvironmental Specialists (AGS)** is a UK based non-profit making trade association established to improve the profile and quality of geotechnical and

geoenvironmental engineering. The membership comprises UK ground investigation contractors, consultancies and laboratories as well as a few general contractors and individuals.

The AGS has a number of Working Groups, including the Data Format Working Group which created and now maintains and promotes the AGS Data Transfer Format. Both of the lead authors of this report, Tony Daly and Neil Chadwick, are current members of this group.

The last major change of the format was the release of AGS4 in 2010. The latest minor revision was version 4.0.4 issued in March 2017 (AGS, 2017).

The most relevant current initiatives are listed below.

- Overhaul of website (new version for September 2017)
- Extension of AGS format to cover piling data, in collaboration with the Federation of Piling Specialists (FPS). A first draft has been issued for comment.
- Extension of AGS format to cover grouting and sprayed concrete lining tunnels in the early stages of development.
- Extension of AGS format to cover interpretative information. This was commenced several years ago but put on hold pending completion of the BIM for subsurface project (discussed above). It has now been agreed that this will be taken forward and a subgroup has been formed. It is likely to be developed in parallel with the proposed development of geotechnical IFC with buildingSMART.
- Incorporation of advanced laboratory testing into the format, with a draft currently being reviewed.

- Format for contamination and chemical testing data is under review in response to industry comments.
- Preliminary discussion of what the next major revision (AGS5) should include. An early objective that has been agreed is that AGS5 should be capable of being the primary means of providing the investigation data, with the factual report being a secondary view of that data.

With respect to extension of the format beyond ground investigation, the AGS Data Format Group is keen to promote and guide such development, but would prefer other relevant bodies, e.g. the FPS for piling data, to ultimately take full ownership. Any such extensions would be standalone transfer formats, albeit sharing common rules and conventions with the current AGS format.

At present, in common with most similar groups, most development work is carried out 'in kind' by the members.

The fees charged for registering for use of the format are being increased with a view raising additional funds, which could be used to pay consultants for specific items of work, e.g. creating new guidance.

The work of the AGS Data Format Working Group is ongoing. Highways England could support this by providing input on potential revisions and improvements, especially those identified elsewhere in this report. For any major changes or enhancements, Highways England could assist by drafting proposals as part of Highways England projects, then taking them to AGS for adoption. This would considerably speed up the process of change given that AGS often lacks the resources to work up major changes in a timely manner. Useful links:

- AGS Data Management Working Group home page:
<http://ags.org.uk/group/data-management/>
- AGS format introduction web page:
<http://www.agsdataformat.com/datatransferv4/intro.php>

6.4.3. DIGGS



DIGGS (Data Interchange for Geotechnical and Geoenvironmental Specialists) is a data transfer protocol for transfer of geotechnical and geoenvironmental data, i.e. similar in scope to the AGS data transfer format. The DIGGS project is based in the USA.

Work on DIGGS started back 2004. In the early years there was substantial UK involvement led by AGS and the Highways Agency. CIRIA CON125 (see section 6.1) included recommendations relating to development and use of DIGGS. There were also proposals for DIGGS to extend beyond investigation to construction operations, e.g. piling. DIGGS version 1.0 and accompanying documents were released in 2008.

However, the DIGGS project then lost momentum. It was not implemented by software vendors. The UK participants including AGS and Highways Agency did not stay involved and AGS developed their version 4.0 format instead.

DIGGS continued to develop, albeit more slowly. The most recent work, taking it up to release v2.0b in May 2016 (Data Interchange for Geotechnical and

Geoenvironmental Specialists, 2016) was administered by the Ohio Department of Transportation with support from the US Federal Highways Administration. The Geo-Institute of ASCE is the current primary sponsor.

The current DIGGS coverage is similar to AGS format but its schema is based on XML which is more flexible compared to the strict relational hierarchy of the AGS format. However, DIGGS is still not supported by established software vendors. We are not aware of it ever being used in the UK.

At present, DIGGS as a schema does not offer any significant advantage over the AGS format. Given its lack of software support and lack of usage in the UK, there appears to be no merit in pursuing DIGGS further at the moment.

Useful links:

- DIGGS home page: <http://diggsml.org/>
- Introduction to DIGGS:
<http://diggsml.org/sites/default/files/attachments/Introduction%2Bto%2BDIGGS.pdf>

6.5. CON125 Review

CON125 "Review of Electronic File Formats for the Exchange of Geotechnical Information used in Transportation Schemes; July 2006" is a consultancy report authored by Mott MacDonald for CIRIA¹⁵ with support from Highways England.

It was considered appropriate to review the findings and recommendations of CON125. The report was written over ten years ago and concentrated primarily on data transfer formats in geotechnical applications, including site investigation and asset management.

The following presents the key findings and recommendations and discusses the relevance to the current situation. It's useful to see the continuity of some of the requirements and changes in others.

6.5.1. Background

CIRIA CON125 was set up to review the existence and use of data transfer formats for geotechnical applications. The project aimed to build a cross industry forum to lead to improvements in the quality of current practice, improvements in the knowledge in this field and improvements in the scope of future achievements.

The main findings were as follows:

"A review of existing data transfer formats relevant to geotechnics in transportation schemes was carried out. Although many data transfer formats were found to exist, not all were in active use or supported by software applications. There is a trend to the development of open source XML data transfer formats, but as yet these are not widely supported by software developers, who prefer to use proprietary binary or ASCII file types. The most widely used data transfer formats relate to general data types such as mapping and GIS¹⁶ information, images and databases. Most of the specialist

¹⁵ Construction Industry Research and Information Association

¹⁶ Geographical Information System

geo-data transfer formats relate to ground investigation information, with little development of data transfer formats in other parts of the supply chain.

Despite data transfer formats being essential to a successful GDMS¹⁷ application, there is little guidance on the transfer formats themselves. This demonstrates that although data transfer formats are important, there are other elements that are also key for GDMS implementation. These include a relevant policy framework with leadership support, training and education of Clients and Users, software development and adoption and far sighted financial investment.

Storage and transfer of data, particularly by government bodies may also be subject to certain statutory requirements or government policy. Whilst the legal framework for data is driven by public access to public and personal information, data managers need to be aware of initiatives that may affect access to, or transfer of, their data. Currently there are no requirements specifically aimed at geotechnical data management, although some aspects of this information, if owned by government bodies and also classified as environmental information, may be subject to public access requirements. In the future however, there are likely to be drivers for greater European integration of spatial data and possible harmonisation of its storage and transfer. This would require pan-European data transfer formats.

The review of data transfer formats, standards and guidance demonstrated the significant gaps in data transfer formats for the majority of the supply chain. Whilst in the field of ground investigation concerns were expressed that the existing industry standard data transfer format was not always used correctly or even implemented at all.”

The main recommendation were as follows;

“Development of industry best practice guidelines including documents targeted at Clients or Sponsors of transportation projects, as well as at Users of geotechnical data.

Inclusion of data transfer format requirements in published specifications for ground investigations.

Training of future data managers at university level through increased university links and use of teaching packs.

Education of Clients or Sponsors in good data management through a CIRIA led forum.”

”Training of data users in current best practice as well as providing information on changes to practice that will occur in the future.

General support for the development of “Data Interchange for Geotechnical and Geoenvironmental Specialists” (DIGGS), including its development and promotion.

Specific technical support for the development of a geo-asset data transfer format. This will involve bringing together industrial partners to support and lead initiatives in this area.

¹⁷ Geotechnical Data Management System

Specific support for current initiatives for the development of construction data transfer formats, starting with piling and moving into other areas.

Commission a broad review of data transfer formats applicable to conceptual and feasibility study data. This will have an emphasis on spatial data and should therefore aim to build links across other disciplines.”

6.5.2. Assessment

Findings

The findings of the CON125 report are as relevant today as they were when they were written. The exceptions being “XML¹⁸” and “*pan-European data transfer formats*”

The momentum behind the move towards XML has diminished, not just by the geotechnical industry, but also by the IT industry. XML once provided a solution to transferring nested data in a single file over the internet. Since CON125 was written a new technology has been replacing XML. The new technology is a subset of JavaScript called JSON¹⁹ and allows nested data to be transferred over the Internet without the complexity of having to analyse the XML structure nor having to deal with the XML standards, which became overly complicated for the task.

There has been no drive for pan-European data formats and the regulatory regimes around data storage and transfer have not materialised, other than standard data handling protocols.

It should be noted that there is currently no national or international official "standard" for the interchange of geotechnical information. The AGS is a de-facto standard, but this may be superseded by BS1192 as it widens its scope to included non-building information.

Recommendations

Some of the recommendations presented in the CON125 report have been implemented e.g. inclusion of data transfer formats in specifications, training etc. and some have been superseded by the BIM²⁰ programme e.g. development of a geo-asset data transfer format. The one that should be discontinued is the relating to DIGGS i.e.

“General support for the development of ‘Data Interchange for Geotechnical and Geoenvironmental Specialists’ (DIGGS), including its development and promotion.”

DIGGS is just starting to be tried out in the United States. It is a very complicated system, with a hierarchy that doesn't fit well with UK current practice. As mentioned previously, the technology (XML) on which it's based has become out of date for data transfer and is now used for mainly for document markup.

6.5.3. Comments on Section 7 of CON 125

Short term recommendations

“the implementation of XML for the AGS data transfer format and subsequent adoption of DIGGS will lead to changes in current practice.”

¹⁸ eXtensible Markup Language

¹⁹ JavaScript Object Notation

²⁰ Building Information Modelling

As discussed in the previous section the use of XML and the support to DIGGS has not stood the test of time. The AGS Data Format Working Group decided not to use XML as a replacement for CSV²¹, mainly because the industry wouldn't have been able to support it and the advantages to move to a different format were not clear. The industry is relatively comfortable with basic technology as the staff using data transfer are primarily engineers and technicians, not IT professionals.

The need to update the AGS data format still isn't compelling, because the industry still works on a desktop-to-desktop model, however if significant improvements are to be made in productivity and data sharing a new format, probably using JSON will be required. There is no reason why the CSV and JSON formats couldn't run in parallel as long as they share the same data dictionary.

“direct training is also recommended in order to assist in improvement of current practice.”

In most sectors training is provided by the industry or 3rd party training vendors. Unless there is something Highways England-specific, Highways England should help by sponsoring or promoting the services of a training organisation(s), but not necessarily provide it themselves.

Long term recommendations

"7.2.2"

"(i) Maintenance and Asset Management Data Transfer"

This requirement has been superseded by BIM. Although progress is slow, Highways England have started to establish an interchange format using the ADMM²².

"(ii) Construction Data Transfer"

This requirement has been superseded by the BIM initiative.

"(iii) Conceptual/Feasibility Data Transfer"

This has not been carried forward and doesn't seem to be within the scope of BIM. Some organisations are using GIS, but not many. This is a topic that should be taken forward.

"(iv) Decommissioning Data Transfer"

The recommendation was to take no further action. This is agreed. The ADMM and BIM have partially superseded this requirement and there will need to be liaison with 3rd parties at the time of decommissioning, if records are transferred. Otherwise records remain with Highways England via a Lord Chancellor's Instruments for record retention.

²¹ Comma Separated Variable

²² Asset Data Management Manual

7. Technology Review

7.1. Current Status

Over the last 20 years the paradigm for the use of IT in geotechnical engineering has been:

- collect/obtain data,
- input (import or manually enter) into desktop software application,
- analyse and report to an analogue format,
- provide digital data (AGS) format

Whilst the media of reporting is now typically digital (PDF format) the report itself is static and a facsimile of a paper equivalent, such that if the report is printed it is identical.

The digital (AGS) data is generally, but not always issued at the end of a site investigation.

There have recently been changes to move away from a desktop application for storing data, towards an enterprise RDBMS²³ database. This allows multi-project information to be stored on the same system and in theory simplifies data management. The negative aspect of an enterprise-level system is the inflexibility to meet project-specific requirements within short time periods.

Whilst desktop applications have worked well, there are advances in technologies that will drive an alternative model to the method of working in the near future.

These technologies are:

- mobile hardware and software
- wireless communication
- HTML5
- Web services
- changes to software licensing

7.2. Mobile Hardware and Software

The mobile tablet is now ubiquitous in domestic life. It is used primarily for consuming information such as e-books, web pages and email. Because of the numbers produced, the competition in the market and available technology, the cost has reduced and the performance has increased. The evolution of the tablet has to some extent replaced the advances in desktop hardware and software, which has largely remained static, other than improvements in memory and storage.

Laptops are still widely used in the industry, but hybrids (a laptop with a detachable, touch-sensitive screen, or a tablet with a detachable keyboard are becoming more commonplace)

²³ RDBMS = Relational Database Management System

Mobile devices will become more prevalent as they become cheaper, and engineering and asset information becomes available in ways that can be consumed by mobile technology. e.g. 3D models, virtual reality etc.

7.3. Mobile Data Capture

Driven by the domestic consumption of news and information, the expectations of clients and supervising engineers is that data should be available from site or the laboratory in a minimal amount of time after the activity is complete. Long periods waiting for paper records to be collated, data to be re-entered, and reports printed are considered to be unacceptable.

Mobile devices are increasingly being used for data capture. Whilst this has been the case for geotechnical asset management in Highways England for a number of years the rest of the workflow, i.e. site investigation and monitoring have not adopted the technology widely. It has been used successfully for borehole logging (drillers' data) and in some cases engineering logs, but the wider adoption of mobile technology for general data capture e.g. insitu tests, site diaries, laboratory testing has not taken place. This is probably in part due to the confined desktop paradigm that applications must be written for the intended purpose i.e. the application much be for geotechnical logging etc. BAM have adopted a different approach, e.g. to use a generic form creating application to configure for all types of data.

7.4. Document formats

The primary document format for transferring information is PDF. This is a requirement of HD22, which in turn reflects the requirement of the National Archives. The ability to hold reports in PDF format is also built into Highways England's geotechnical asset information system and associated processes. Specific software (HA PDF Toolkit) is provided to the supply chain free of charge in to enable indexed PDF format reports to be uploaded to associated metadata on HAGDMS.

The PDF rendering of a document is intentionally fixed to represent the printed page, which has the advantage of preserving the document in exactly the same format in which it was published. This is of course very useful for records and documents which have a legal or quasi-legal status.

Whilst the PDF report format serves a very useful purpose, it is not suited to viewing on mobile devices. The reflow of text is not always supported and the author needs to ensure that text reflow is enabled when the document is created. PDFs also require download, which takes up mobile bandwidth and storage.

The use of mobile devices has seen an increase in the consumption of digital material. Users are familiar with reading text on web sites and on e-published documents that reflow the text according to the screen size. They are also increasingly comfortable with using interactive content such as maps, videos or graphics. With the shift from the "paper-based" layout the originally intended format of documents is becoming less important than the content. The trend for consumption of information on mobile devices will only increase over time, so it would pay to start preparing for it now.

The move away from the "paper-based" layout offers opportunities to improve the communication of information. For example exploratory hole logs are traditionally split on an A4 page basis. This makes reading the log of a deep borehole difficult. The web browser page is effectively infinite, so the log could be represented as a single, continuous entity.

Other benefits of using an interactive interface to communicate information include:

- interactive maps: zoom, toggle visibility of layers, show information about locations etc.
- interactive tables, searchable data, drill down etc.
- interactive charts, zoom, toggle visibility of points etc.
- interactive 3D models, zoom rotate, toggle visibility of objects etc.

Providing the reader with the ability to explore the information should enhance the experience and allow a deeper understanding of the data.

The report will be more data-driven, i.e. charts and maps can be produced directly from the data, without having to be processed using spreadsheet or CAD²⁴ software. It should also help with the speed of delivery of the report as the author will no longer be required to provide individual printouts for each combination of parameters.

Wider considerations for records management (Common Data Environment) on a project include the ability to index and search through the text of documents in the way that a Google™ search operates across web pages. This allows greater access to information, without having to pre-process the PDF.

Of course where a "fixed" version of a document is required a PDF copy may still be appropriate. A document can easily be converted into different formats as long as the source is supported by the file convertor.

This report has been prepared using Markdown²⁵ and published in both a PDF and HTML (browser) format to demonstrate the concept.

7.5. Wireless communication

Apart from a few "black spots" in the more rural areas, wireless communication is now commonplace, both inside and outside of the office. Either using the mobile telephone network or dedicated wireless networks or hotspots. Users now expect to be able to view maps and get access to other information their mobile phones and tablets.

The way that the majority of information is transferred over the wireless networks is accomplished by moving small packets of data as needed, rather than large chunks of data; the exception being where discrete files are downloaded e.g. a PDF document or AGS²⁶ format data.

Wireless communication will inevitably get faster, more available and more affordable. It is already expected that project and asset information should be

²⁴ CAD = Computer Aided Design

²⁵ Markdown = A simplified text markup language that converts to HTML and other formats.

²⁶ AGS = Association of Geotechnical and Geoenvironmental Specialists

available on site or out of the office, however the systems to support this in Highways England and within its supply chain are not currently, widely available.

It is recommended that data/information formats be developed with ease of transfer over mobile networks in mind. This involves adopting Web standards²⁷ where possible.

7.6. Document databases and JSON

Document databases, sometimes referred to as NoSQL databases, are a new technology that provide an alternative way of storing data to a conventional relational database (RDBMS). Instead of holding the data in tables connected by common fields, document database store data in discrete packages of information, usually in JSON format.

The key advantage of a document database over an RDBMS is that the data structure does not need to be defined and maintained. It is very useful for storing data which is similar but does not have exactly the same schema.

For instance AGS format data files can vary in schema from project-to-project, depending on the AGS version current at the time of the investigation and specific data that needs to be captured for the scheme. To hold the data for all the projects in a single RDBMS would require changing the table fields and result in redundant data rows/columns.

Using a document database the AGS format data can be stored without having to alter the database schema.

Whilst document databases do have their limitations, especially where data is being changed very frequently, the appropriate use-case for Highways England would be the storage of AGS data for subsequent analysis and visualisation.

7.7. Recommendations

Highways England should be aware of emerging technology to support their use of geotechnical information and to encourage the supply chain to adopt smarter ways of capturing, storing, analysing and presenting data.

The use of internal innovation funding should be considered to assist with the development of technological solutions to improve productivity.

²⁷ Web standards = [Link to Web standards](#)

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