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Case study - The real life benefits of Geotechnical Building Information Modelling

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Abstract. Is Building Information Modelling (BIM) a case of the emperor's new clothes or are there real benefits to it for the geotechnical industry? The basic premise of BIM is for organisations to collaborate and share information through the whole project, from initial conception, design, build and maintenance but what this translates to, how it is achieved and what the benefits are is not clear to a number of geotechnical consultants. This paper will explore what BIM means to the geotechnical industry by looking at real world examples of geotechnical involvement in BIM.

Keywords. BIM, Building Information Modelling, Data Transfer, Case study, Geotechnical Data Management, AGS

1. Introduction

There is big impetus behind BIM in the construction industry; it is primarily for projects where total spend is more than £50 million however it is anticipated that the majority of other smaller projects will also use BIM, with the UK Government Construction Strategy [1] stating:

> "Government will require fully collaborative 3D BIM (with all project and asset information, documentation and data being electronic) as a minimum by 2016."

One of the main benefits of BIM is the cost savings generated by the reduction of unforeseen problems which are highlighted by the production and update of the prototype model. By better understanding and prototyping the design more unforeseen circumstances will be removed. The general hypothesis is that a better understanding of the project from the collaboration of design data from the various parties will help minimise problems later in construction. Problems resolved at an earlier stage will cost considerably less than rectifying them later in the construction process.

The graph in Figure 1 by inspired by Patrick MacLeamy's Effort Curve [2], illustrates the ability to reduce a project's costs if informed decisions can be made earlier in the design stage.

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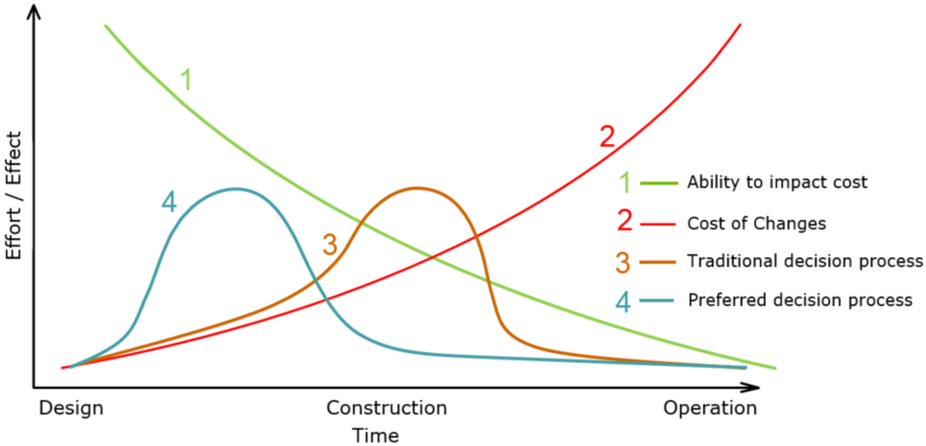

Figure 1. MacLeamy's Effort Curve

The AGS Guidelines for Good Practice in Site Investigation [3] states "An early investigation allows the identification of any ground-related risks associated with a development so that they can be effectively managed and associated costs controlled". It goes on to say "Site Investigation should be seen as an investment which has the capacity to optimise design and hence add considerable value to a project" The requirement for quality investigations is also made by Chapman & Marcetteau [4].

In a construction project the typical site investigation costs are no more than 0.1% of the overall building cost, although this may be more in infrastructure work. The consequences of delays due to these unforeseen ground conditions are far too common and primarily lead to over spends in the project.

The National Economic Development Office (NEDO) conducted a review of 5000 industrial buildings and found 50% overran by at least a month [5] of which around 37% of the overruns in the projects were due to ground problems. In another report The National Audit Office [6] quotes an Office of Government Commerce study which found that 70% of a range of public projects were delivered late and 73% were over the tender price

Reducing risk from the unforeseen ground conditions should be a major aspect of the geotechnical design process. Ground problems are one of the major causes of project delay and when they occur they are normally difficult and expensive to rectify. This illustrates the need for a quality Desk Study and Site Investigation as part of the BIM process.

2. How to Apply BIM to Geotechnical Data

There are a number of approaches that can be taken with implementing BIM with the geotechnical processes; the first is the use of digital transfer to allow geotechnical data to be shared within the BIM process.

The idea of sharing data is nothing new to the geotechnical industry in the UK. The Association of Geotechnical and GeoEnvironmental Specialists (AGS) started to develop a digital transfer format in 1989. The subsequent format, known as AGS Data, has become a common means to transfer geotechnical data from one party/process to another within the geotechnical workflow, as illustrated in the Figure 2. The format is now an established part of the UK geotechnical industry. Many software applications use it and the AGS format is often specified as part of project deliverables.

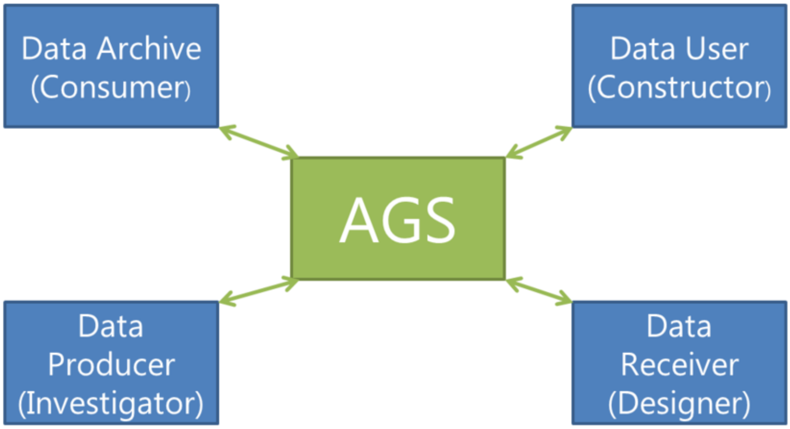

Figure 2. AGS format transfer

The collaboration and sharing of digital data is one of the cornerstones of BIM. As discussed later, having a clear specification on the regular delivery of AGS data contributes significantly to making geotechnical projects BIM compliant. With the AGS file the latest data is readily available and can be directly used in many systems, unlike a PDF report.

An example of the philosophy of sharing digital data as part of a collaboration information management system is the Highways Agency Geotechnical Data Management System (HAGDMS).

2.1. HAGDMS, an example of sharing geotechnical data within a BIM

HAGDMS is a web-based system for the complete management of Geotechnical Assets on the trunk road network for the Highways Agency. It uses many of the principles involved in BIM. It is designed for the whole life of a project, bringing various information and data together in one location to allow geotechnical professionals to make informed decisions. The system has been very successful over the 14 years it has been in operation. Since its implementation it has grown to incorporate many datasets and is the heart of many workflow processes in the Highways Agency and its wider network of consultants.

HAGDMS covers all aspects of geotechnical and drainage information including, borehole data, scanned report archives, earthwork condition reports and maintenance requirements and drainage network connections for the whole of their road network in England.

HA GDMS has been successfully rolled out to a community of over 1,000 users in over 300 national offices by Mott Macdonald in association with Keynetix. The entire system can be accessed via a secure login page at www. hagdms.co.uk. HAGDMS has now become one of the largest geo-referenced geotechnical and drainage asset management tools in the world, with 220,000 observations on over 45,000 geotechnical assets and more than a million drainage assets. The system provides access to nearly 200 mapping layers, 114,000 photographs and sketches, 20,000 geo-referenced files and 15,000 downloadable reports.

HAGDMS is a vital source of geotechnical data for BIM projects. Although the web viewer does not include 3D Visualisation the AGS data downloadable from the system can be easily viewed in a 3D environment using desktop applications. This extensive data set allows geotechnical professionals fast access to a comprehensive model of the information available at any particular site.

3. Geotechnical Building Information Modelling

Mott MacDonald has taken being BIM compliant further; not only do they deliver geotechnical data for inclusion in BIM, but also apply BIM principles and practices directly to the geotechnical process. The following section of this paper outlines the approach Mott Macdonald use in applying Building Information Modelling techniques and workflows for the whole life of the geotechnical project, from the tender to file archive.

Mott MacDonald has been refining the Geotechnical Building Information Modelling process for a number of years using expertise from a history of geotechnical data management combined with CAD and 3D modelling skills. The primary products Mott MacDonald use for their Geotechnical BIM processes are HoleBASE SI and AutoCAD Civil 3D.

3.1. Continual refinement of the (3D) model

Mott MacDonald's approach is to continuously refine the geotechnical model throughout the lifetime of the project. As more data is collected the model is refined and constantly combined with the complete project model to check against updates and changes to help minimise unknowns and risk. Within a project the model will be continuously refined through all the major stages as shown in Figure 3.

- Desk Study
- Ground Investigation (GI)
- Ground Investigation Report (GIR)
- Ground Design Report (GDR)

3.2. Desk Study

At the desk study stage, the historical and publically available data is collected and an initial model is defined together with general project related information. This may include, but is not limited to: route maps, mining maps, geology maps, ordnance survey maps, and environmental data. These together with data from the other members of the project are combined to generate the initial model.

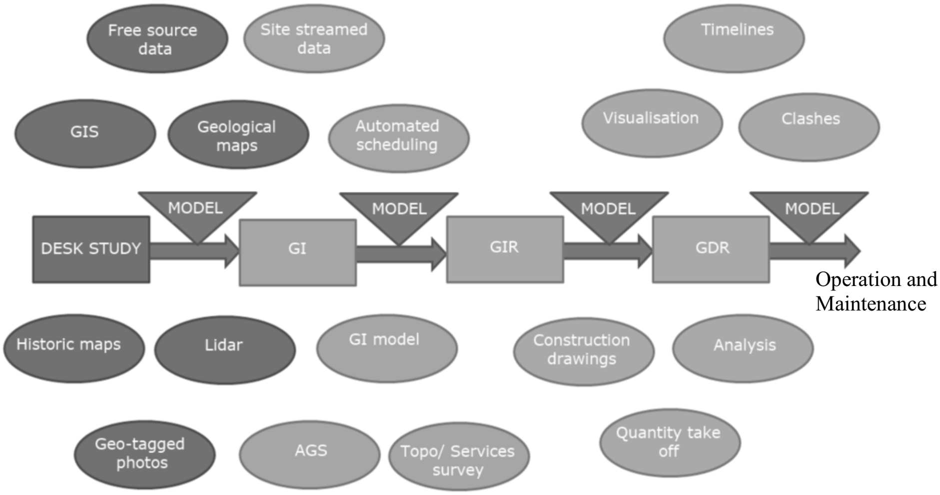

Figure 3. Continual refinement of the model

There has been a major change in desk study data availability and, more importantly, accessibility in recent years. Mott MacDonald are making full use of this and incorporating much of the available data within their initial model in a 3D environment as shown in Figure 4. Data sources used at this stage include:

- Ordnance Survey Open Data:
  - Digital Terrain Models: 50 m grid of heights and 10 meter contours
  - Road and Street Maps
- British Geological Survey: Open Data
  - DiGMapGB-50: bedrock geology, superficial deposits, linear features
  - Borehole Index

The desk study is used to ascertain possible problems the site might yield and what type and level of investigation is required to minimise risk of unforeseen ground conditions. Having the data readily available and in 3D gives a better insight to potential problems of the site.

Data can come from open source and more specialised sources too – for example, on High Speed 2 railway between London and Birmingham, Mott MacDonald compiled a BIM ground model using data from the Coal Authority to confirm the depth of coal seams and the presence of nearby surface mine workings. This information all helps to plan more appropriate site investigations.

With an initial model in place, BIM becomes an instrumental tool for designing ground investigations. Mott MacDonald engineers use the model to identify the best locations for exploratory holes. With these positioned in the model, it is easy and quick to take off quantities and calculate the ground investigation's cost. Setting out data can then be fed directly into surveying equipment, or extracted as 2D drawings.

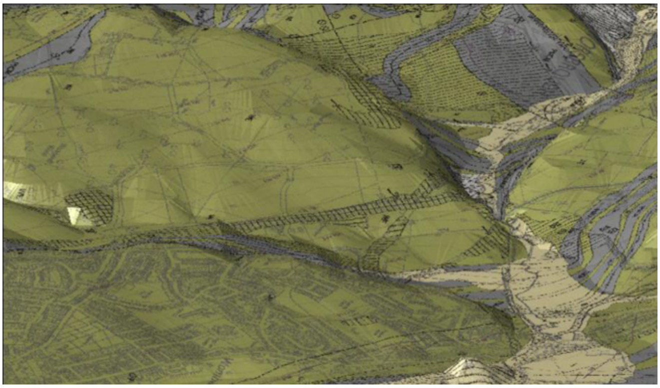

Figure 4. British Geological Survey and Ordnance Survey data

3.3. Ground Investigation

Traditional methods of working in the UK are to instruct the contractor to conduct the site investigation. The work will be conducted and a report submitted to the consultant. This whole process can take weeks, during which time many aspects of the job may have changed. Unfortunately, due to time constraints in obtaining the report and data from the contractor, it is often not possible to refine the investigation resulting in a report that may not be ideal for what was found or the changed specifications. Best case scenario is a delay in the project while an extra investigation is made, otherwise this could lead to unforeseen ground problems and the costs involved in rectifying them.

Modern-day technology, such as KeyLogbook and Pocket SI among others, allows for near real-time data gathering on site. AGS data is sent directly to the consultant's office to be incorporated in the geotechnical BIM model within the same day. This allows Mott MacDonald to react in a timely way to any unforeseen conditions, and make modifications to the site investigation as the information becomes available. Seeing the retrieved data from the SI together with the model data leads to a better understanding. These techniques speed up the whole process which enables a more appropriate investigation to be done for both the ground conditions and the current project specifications.

The GeoBIM process also enables the collaboration between different geotechnical partners. From within the geotechnical model it is possible to highlight and identify sample locations and specify test scheduling. AGS data is used to communicate with the geotechnical laboratories maintaining a consistent and verified means of transferring test requirements and results back to the Geotechnical Model.

3.4. Ground Investigation Report

The Ground Investigation Report includes the geotechnical engineer's expertise in interpreting the facts from the ground investigation. For the process of interpreting this data Mott MacDonald uses a variety of methods including the use of AutoCAD Civil 3D and HoleBASE SI. These and other tools are used to visualise the information to help understand the data and allow the engineer to interpret. This together with the results from lab tests help further refine the geotechnical model, this approach allows the model to be refined further than traditional methods.

Traditionally the geotechnical profession has been concerned that the nature of uncertainty with geotechnical investigations is different to other professions in the construction industry with regard to BIM. Only some of the information is factual and the rest is an interpretation of the facts prepared for the design brief of the project. To some extent this is also applicable to other disciplines; an engineer will design the heating and ventilation system based on the requirements brief of the project put in front of him. However if there are changes to this then his design may well have to change. This is the same in the geotechnical industry and the BIM model can be used to represent this and to check if the project changes. As with all BIM it is best to foresee these problems at the prototype stage before construction starts.

3.5. Ground Design Report

The ultimate goal of GeoBIM at Mott MacDonald is to automatically integrate the model into analytical software. It is intended as part of the interpretation process. Material properties can be added to physical zones within the model.

Work is underway to use the geotechnical model as input into analytical software, with both the geometry and engineering characters being automatically passed to the software. As the engineer alters the foundation designs within the model, the analytical results could be automatically updated. Although this is not currently possible, the geotechnical model is already aiding this process and data can be easily exported and transferred to the analytical software minimising the need to retype.

4. Conclusion

This paper illustrates the importance of including geotechnical data within the BIM process; one of the primary benefits of BIM is cost savings by reducing unforeseen problems. This highlights the need for a quality site investigation to reduce future risk and uncertainty as part of the BIM process.

The UK geotechnical industry is well placed for the inclusion of geotechnical data within BIM due to the history of the AGS transfer format and applying the principles of data capture close to source and transferring digital data. This approach should be available to all as it is simple and easy to implement.

The second approach, as illustrated in Mott Macdonald GeoBIM, of constantly refining the model by using BIM workflows and techniques within the geotechnical process will yield more benefits, which ultimately should further reduce construction problems due to ground conditions. Inherently this approach will generate BIM compliant data that is available for all parties involved in the project and will ultimately lead to less project overruns from unforeseen ground conditions.

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