

The role of geotechnical data in Building Information Modelling

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ABSTRACT

Building Information Modelling (BIM) is becoming an important tool in civil engineering both in the infrastructure design and construction process. BIM uses an intelligent model that provides insight for creating and managing building and infrastructure projects faster, more economically, and with less environmental impact. The rich information in the intelligent model enables visualization, simulation, and collaboration that together allow better decision-making to be possible within the whole project team.

Major infrastructure projects that have a significant geotechnical and structural aspects may implement BIM tools and processes but often seem to neglect the geotechnical aspect of the model. This omission can result in costly mistakes especially when the project is infrastructure based.

This paper reviews the current BIM implementations on major infrastructure projects in the UK and overseas and reviews how the inclusion of the geotechnical data in the BIM model can improve the model's usefulness and the decision making process.

The paper also investigates the reasons why geotechnical data is not included and how these barriers can be removed so that the geotechnical and structural teams are fully integrated.

The paper concludes with a set of recommendations that, if adopted, could allow the engineering design team to produce innovative geotechnical systems and improve the cost-effectiveness of construction.

Keywords: geotechnical data management, BIM

1 INTRODUCTION

There are many definitions of Building Information Modelling (BIM), but The National Building Information Model Standard Project Committee (2008), in the USA defines BIM as:

Building Information Modeling (BIM) is a digital representation of physical and functional characteristics of a facility. A BIM is a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle; defined as existing from earliest conception to demolition.

Not all definitions will entirely concur with the above, but where they do tend to agree is that BIM is the marriage of a technology and a set of work processes. Different definitions put the emphasis on either one or the other, dependent on author perspective, but there is widespread acceptance that they would be incomplete without both parts. To ensure that this paper remains compact it will primarily focus on the aspect of BIM work processes with a secondary, smaller, consideration covering technology that could be used.

It's important to note that in order to produce coherent model, collaboration within disciplines isn't enough. Everyone involved must work together. BIM is by its nature multidisciplinary. This intelligent model-based process should provide insight for creating and managing building and infrastructure projects faster, more economically and with less environmental impact.

Technology is a crucial part of BIM and any BIM software portfolio should include comprehensive solutions for design, visualisation, simulation and collaboration that use the rich information in the intelligent model to inform better decision-making and break down the barriers to better business.

BIM is not just 3D CAD. The mistaken belief that it is, prevents the realisation that BIM isn't just another incremental improvement of existing methods, in the way that CAD improved upon hand drawing. It isn't a better way of doing things; it's a way to do better things. Issa, Suermann and Olbina (2009) sums up the importance of the move to BIM in their paper - "The transition to BIM is different from the move to CAD because CAD did not significantly alter business processes, but simply increased the speed at which centuries-old traditional tasks were completed through electronic means."

To illustrate how BIM differs from CAD it is useful to consider a recent UK project that has been utilising BIM.

2 EXAMPLE OF BIM

2.1 M25 widening

The M25 motorway that circles London is one of Europe's busiest highways. In 2009, England's Highways Agency awarded a AUD\$10 billion contract to the Connect Plus consortium for future development, operation and maintenance of the M25 motorway. Part of that contract includes widening over 23 miles of the motorway's north western quadrant and 17 miles in the northeast from 3 lanes to 4. Construction commenced in the spring of 2009 and must be completed before the London 2012 Summer Olympics. This requires finishing construction in approximately half the time it typically takes for a project of this scope.

In addition to the fast-track schedule, the Atkins & Skanska Balfour Beatty Joint Venture project team faces several critical challenges. The widening of the motorway is constrained by the boundaries of the current road. The design also incorporates a central reserve barrier, additional gantries, and new roadside lighting. All of these features must fit into the existing boundaries of the M25, requiring several new cuttings and embankments to be constructed and exacting design and construction coordination. Furthermore, 3 lanes of traffic in each direction must be continued at all times during construction of the new roadway, necessitating careful construction planning.

To help meet the aggressive design-build schedule, the project team relies on a coordinated, accurate design model. The integrated design model helps the team visualize the whole project, including all above ground and underground components, and non-physical aspects of the design, such as safety and access zones. The designers use software technology to help identify and correct clashes that would be very difficult to detect using 2D documentation. Extensive use of sheet piling was made on the project in order to contain the widening inside the existing corridor boundary wherever possible. Access to the BIM model including geotechnical information was crucial to the construction team when availability of steel or piling plant offered an opportunity for just-in-time design change in order to optimise either cost or schedule.

Following release of the design to site, the project team adapts the design model to create a construction model. The team enhances the design intent model to create a virtual construction model that incorporates additional elements such as a more realistic version of the new retaining walls (for visualization), point clouds from laser scans, and temporary works. When necessary, the designer's site representative team updates the construction model to better reflect on-site design changes.

The extended project team, including onsite construction personnel, can view the construction model from their temporary offices. The use of a consolidated, more accurate construction model means everyone can access the same up-to-date, more realistic project information when assessing how best to perform construction tasks.

2.2 M25 Dataroom and HAGDMS

Tenderers for the M25 project had access to all geotechnical assets and environmental considerations via an online dataroom. This dataroom was provided by snapshotting the data stored in the Highways Agency Geotechnical Data Management System (HA GDMS) system and where applicable the data was made available to tenders in a format that could be incorporated in a BIM model.

HA GDMS is the principal tool for the management of geotechnical hazards and risks throughout the full life-cycle of the UK highway network, i.e. from initial feasibility studies, through design and construction, into operation and towards decommissioning or redevelopment. The system contains a

national model of all highways-related geotechnical assets and boreholes held by the HA and their agents, including mapping, aerial photographs and LIDAR. Related to the model are geotechnical reports, geotechnical inspections and maintenance records.

It is worth noting, currently HAGDMS is primarily a 2D system which stores 3D geometry with certain assets, but many of the benefits of full 3D BIM are still obtained.

One of the BIM principles is to help in the management of the whole life of the construction and the use of the historical data from the structures that were to be updated on the M25 widening is a good example of how the model can be reused later in the project life cycle and not just during the construction phase.

2.3 Geotechnical Data

Data is the primary deliverable for any site investigation. However in many cases the data is converted into information and presented to the client by means of borehole logs, site plans and charts etc. It is important to note this difference between geotechnical information and geotechnical data as any additional representations (plots etc) or incorporation into a BIM environment would either require access to the data or rekeying of the original data.

It is therefore important that the site investigation data is available in a format that can be incorporated by the consultant or BIM teams no matter what software they are using. The standardisation of electronic data deliverables has significant advantages for the data provider and the data producer on any project, especially if the standardisation adopted is already used by both parties.

AGS data format is a Comma Separated Variable (CSV) style text data format introduced by the Association of Geotechnical and Geoenvironmental Specialists in the UK (AGS 1992, 1999, 2010). The benefits of using the format have been well documented by Wathall & Parmer (2006), Richards and Chandler (2006), Chadwick et al (2006) among others and the format is widely used within the UK and HK and commonly available in Ireland, Singapore, Australia and New Zealand.

Where AGS data is widely used it is interesting to observe how this data is shared between the construction parties. The production and sharing of data is common between site investigation companies, laboratories and consultants but it is rarely shared beyond this point. Our interview research has shown that this is also true with geotechnical data for BIM and the main hurdle that consultants are face is the problems with sharing interpreted data.

Data gathered from a site investigation is factual information. However it very quickly becomes interpreted data once you start to review and use it. One of the first jobs of the consultant is to identify which geological layers each borehole stratigraphy relates to. This is interpretation, even at this initial level. This interpretation is then extended further when the consultant determines how the layers may connect with each other to produce a 2D section or 3D model.

When dealing with interpreted data is it important for the reviewer to know how it was interpreted and for what purpose. Misunderstanding the interpretation methods or using the data for an unspecified purpose can result in the data being used incorrectly and this is the concern that consultants have and their main reason not to share interpreted data with other members of their team. Consultants often prefer to offer them consultation services to provide interpretations for the purpose the team require.

During the rest of this paper we will consider the factual and interpreted geotechnical data as separate BIM inputs.

2.4 Benefits of BIM

In order for BIM to realise its true value over the whole lifecycle of a project all stakeholders must be engaged. In infrastructure projects especially, this means that government must be involved.

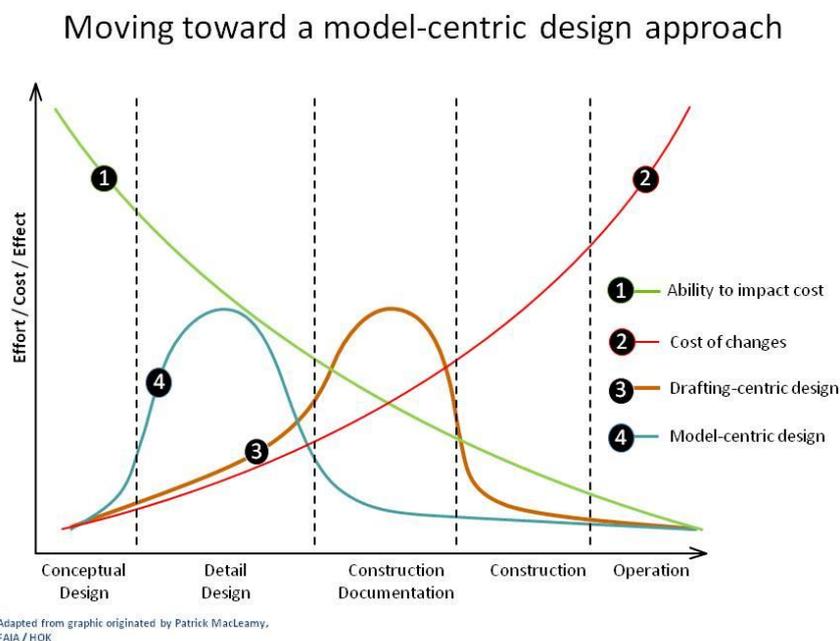
In 2011 the UK government announced that by 2016 it intended to require collaborative 3D BIM (with all project and asset information, documentation and data being electronic) on its projects. The benefits of supply-chain integration in the construction sector are largely understood in terms of performance improvement, greater project 'certainty' and reduced risk. One of the key factors in

achieving successful integration is the accuracy, effective flow and intelligent use of information, which BIM – by requiring interoperability of information – will encourage.

In addition to design and build benefits, one of the main value-added applications of BIM is in the post-construction phase, through the on-going management of assets for optimum value in space utilisation, running costs and energy/carbon reduction.

In September 2009 Paul Morrell, The UK Government’s Chief Construction Advisor, presented a short paper to the Government Construction Clients board outlining an Industry working group, to provide a report on the potential future use of BIM. The final report by the Government Construction Client Group (2011) provides Government Clients with a suggested roadmap and strategy to enable the progressive use of BIM on Government construction programmes as well as providing a framework for procurement and delivery standards. The report also considers the training and support required to enable the industry to rise to the BIM challenge.

To illustrate the limitations of traditional infrastructure design and construction processes, the chart below maps effect, cost, and effort throughout typical project phases, going from conceptual design, to detailed design, to construction documentation, to construction, and finally, maintenance and operations.



Moving towards a model centric approach – Patrick MacLeamy AIA/HOK 2009

Consider curve 1 first, in a typical traditional project, as progress moves from preliminary design to documentation and into construction phases, it’s clear that the ability to impact the costs and functional capabilities declines, and inversely (curve 2) the costs of such changes are more and more expensive as we move closer to the construction phase. Traditional design process (curve 3) enabled by CAD focuses the majority of team efforts during the construction documentation phase, little effort is put in preliminary and schematic design phases, and less after the drawings are created. This means that changes occurring during this phase and even more so into construction, will be very costly to execute. But, in a collaborative design process, where key participants are brought in earlier, and clear goals are set, the preferred design process (curve 4) would aim to shift efforts much earlier in the design cycle, spending more time up front to make better design decisions. With this process, and collaboration based around building information modelling as a catalyst, construction documents become a by-product of the design effort.

Adoption of this type of process will lead to an increase in efficiency and optimised project performance. The result is a more model-centric approach, where more cost and effort is spent earlier in the project.

2.4.1 Benefits of incorporating geotechnical data into the BIM

One of the major benefits of BIM is being able to model different options and refine design with the view of minimising the risk in the construction process. Unlike the manufacturing industry, the construction industry cannot produce physical prototypes and BIM provides a means to optimise the design in the virtual world and reduce unknowns and risks (digital prototyping).

The process of conducting a site investigation is both costly and time consuming and therefore all the options that the design team consider will not have been fully investigated. If the existing site investigation data has not been shared within the BIM team then they will not have immediate access to what data is available and therefore the level of interpretation the consultant will be able to conduct for them without further investigation.

Often BIM models appear to start from the ground up. They seem to consider the sub surface as homogeneous substance evenly distributed throughout the whole and therefore there is no risk involved in changing the design. Unfortunately it is not that simple and the role of the geotechnical team is to minimise the risk in construction. Soil is never homogeneous and can differ considerably between locations. Likewise the test results on samples from a borehole will only be relevant to that location extrapolating this information across the site is once again in the area of interpretation.

For the full benefits of BIM to be obtained throughout the whole process from conception, to design, construction and maintenance, geotechnical information needs to be readily available to enable design refinements and therefore reduce risk.

BIM is also a valuable tool in helping to optimise the phases of construction as can be seen with the M25 widening example presented above. By having geotechnical information such as the geology predictions, groundwater conditions available to the design teams important information on the suitability for reuse can be determined and incorporated.

BIM is not only applicable to the design and construction phases but throughout the whole life of a project. After the project is completed the BIM becomes an accurate model of the assets constructed. This allows clients to fully understand and control what assets need to be maintained or upgraded as was shown with the use of HA GDMS in the M25 widening example presented above.

2.4.2 Benefits of BIM to geotechnical team

Many of the geotechnical consultants interviewed while researching this paper considered BIM as a one way flow of information. Many had been asked to submit geotechnical data to the BIM model but very few had been made aware of what other data was available to them through the model. It's crucial to remember BIM is a two way process and, it is not just a case of putting information into BIM, but importantly, getting information out.

A major aspect of BIM is to aid communication and collaboration. Having better data sharing should lead to more information becoming available to the geotechnical team, which in turn leads to a more complete understanding of the project elements and informed decision making.

For the geotechnical team it means being able to see both the big picture and the details of the project, having access to the latest site layouts, having access to a range of data which might include mapping and remote sensing data. Having a clear image of the proposed design and full project information readily available will enable the geotechnical team to optimise the various phases of site investigation.

A BIM methodology is also very useful internally within the geotechnical team and SI partners, the concepts of data sharing, collaboration, central data management all apply. Big improvements in efficiency and quality can be seen by having a well planned data journey and management strategy.

The UK Association of Geotechnical and Geoenvironmental Specialists (AGS) states in their Guidelines for Good Practice in Site Investigation :

- “The object of the site investigation is to characterise the ground conditions sufficiently to allow safe and economic designs to be developed and to reduce, as far as possible, the occurrence and impact of unforeseen conditions”
- “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”
- “Site Investigation should be seen as an investment which has the capacity to optimise design and hence add considerable value to a project”

In essence a thorough site investigation is a means of moving the decision making process forward and reducing risk at construction time. These are the same reasons why BIM is being employed on projects.

3 CONCLUSION

Many geotechnical teams are not supplying geotechnical data to BIM systems as they are unable to separate the factual and the interpreted information and are concerned by the possibility of the interpretative data being misused.

Not supplying any data to the BIM team however is likely to increase the risk to the project and not help the geotechnical team deliver the message that early and thorough site investigation can reduce risks to a BIM project.

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Determining a company’s geotechnical BIM strategy is however difficult as projects are varied and what works for one project may not work for others. It may therefore be a better approach to adopt a geotechnical BIM framework which can be adapted to each project. The first step in this framework should always be to consult early with the BIM team and deliver the location of known information to the team as soon as it is available.

The next question for the geotechnical industry to answer is; in what format will geotechnical data be delivered to the BIM team? Currently the AGS format appears to suffice for factual information but does not allow the transfer of interpreted data such as geology surfaces. Should the industry look to extend the AGS format to work with this data or should other formats such as GeoSciML be better suited for this purpose?

BIM will, without a doubt, play a large part in construction teams in the near future and give geotechnical teams the opportunity to share their visions and concerns for the ground conditions early in the project design life. This is exactly what the geotechnical teams want and they should therefore be embracing BIM and helping to move it forward in our industry.

REFERENCES

- The National Building Information Model Standard Project Committee (2008) - http://www.buildingsmartalliance.org/client/assets/files/bsa/NBIMS_Charter.pdf
- Electronic Transfer of Geotechnical and Geoenvironmental Data (4th edition) – AGS 2010 (available at www.ags.org.uk)
- Wathall S, Palmer M J., “The Development, Implementation and Future of the AGS Data Formats for the Transfer of Geotechnical and Geoenvironmental Data by Electronic Means” Proc. GeoCongress 2006: Geotechnical Engineering in the Information Technology Age, (2006).
- Chadwick N., Pickles A.C., Sekulski E. M., “Data Transfer and the Practical Application of Geotechnical Databases” Proc. GeoCongress 2006: Geotechnical Engineering in the Information Technology Age, (2006).
- Richards D.J., Chandler R.J. “The Use of the AGS-M Electronic Data Transfer Format for Large Scale Instrumentation Schemes” Proc. GeoCongress 2006: Geotechnical Engineering in the Information Technology Age, (2006) Stahl, D. C., Issa, Suermann & Olbina (2009) “Use of building information models in Simulations” Precedings of the 2009 Winter Simulation Conference.
- Government Construction Client Group (2011), Building Information Modelling (BIM) Working Party Strategy Paper