BIM Application in Geotechnical Works for Master planning and Construction Monitoring

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ABSTRACT

Implementation of geotechnical data to Building Information Modelling (BIM) can improve the master planning of building development and facilitate monitoring of site construction. At the early stage of design development, application of BIM embedding the site geology, building master layout and associated engineering design elements (i.e., foundations and ELS works, etc.) helps the illustration of different options of building massing, especially for a development with significant geotechnical content (i.e., hillside site, near MTRC tunnel). It can be studied quickly to come up with the most cost-efficient scheme of building plan and information including a balance of optimum choice of volume of soil/rock excavation, extent of formation works, amount of material input, etc. BIM can also help engineers to review the construction sequence for complex geotechnical work including phasing of different kinds of works such as pile foundation construction, site formation and ELS works. Nowadays, creation of the 4D (and 5D) modelling allows the programme to be optimized (and construction cost forecast) and facilitates better understanding of the construction sequence. Simulation for construction method in geotechnical works is developed to allow the construction method to be rehearsed virtually so that the engineers and workers can understand it more before execution. This paper discusses the aforesaid BIM applications in geotechnical works for different building projects including institutional developments. The use of BIM results in better design communication within the design team, as well as with the owners and other stakeholders.

Keywords: BIM, Geotechnical, Master Planning

1 Introduction

In the construction industry, Building Information Modelling (BIM) in an approach of collaborative design is not only commonly used nowadays in the architectural, civil, structural and building services fields, but is also applied in geotechnical works. It can be used to create and manage digital models of the geology such as subsurface soil and rock conditions of a site, as well as the associated geotechnical structures and foundations. BIM can also be used to simulate the geotechnical works sequence, identify site constraints and facilitates construction site management.

Recently the authors have been working on some building development projects that illustrate the beauty of BIM applications in geotechnical works. The following sections describe the use of BIM in masterplanning and construction monitoring resulting in increased efficiency of design, reduction of construction cost, improvement of sustainability and enhancement of collaboration and communication among engineers, contractors and owners.

2 Master planning in Geotechnical Works

Master planning in geotechnical works involves development of a comprehensive plan to manage the geotechnical aspects of construction works such as site formation works, foundation works and ELS

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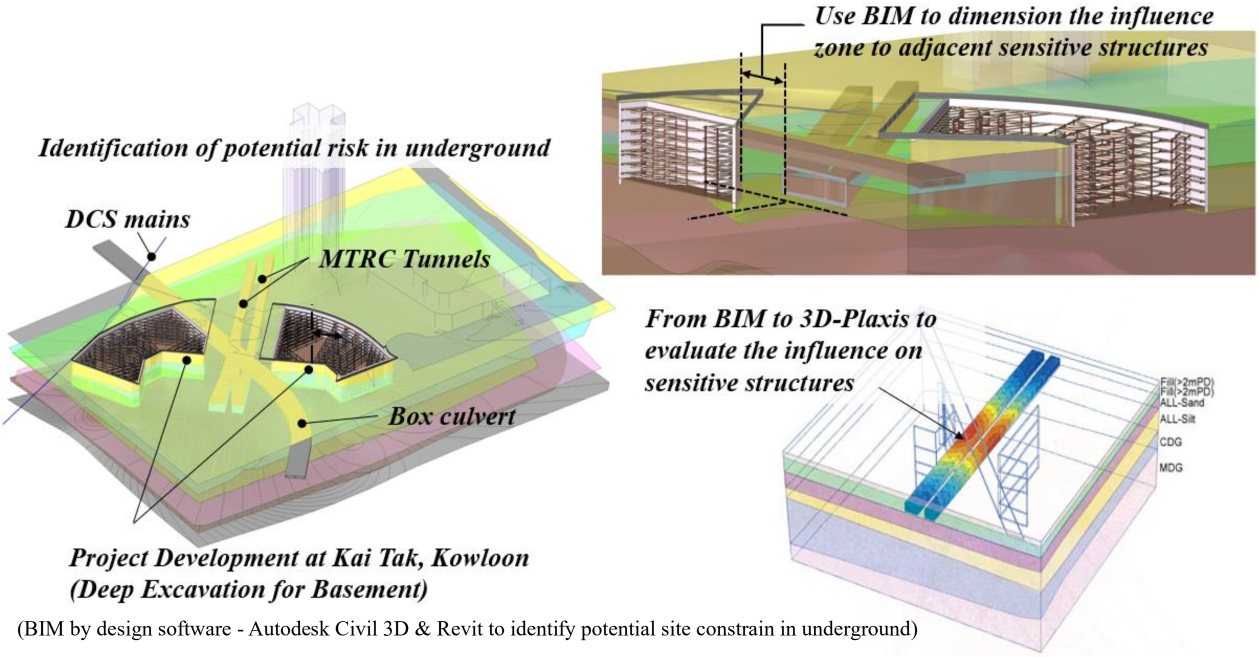
works. BIM is applied in geotechnical works at the early stage of master planning to evaluate site conditions, assess potential risks and develop design solutions to address these risks.

2.1 Identification of Potential Risks

By incorporating the data obtained from desk study, site reconnaissance and ground investigation into the BIM, the designers can enhance their visualization of underground constraints, take good control of the design process, have clear understanding of ground behavior and react faster to potential issues on site. The BIM as shown below demonstration the underground constraints such as MTR tunnels and geotechnical features for the entire project team to have a holistic picture for deriving a master plan for the project. Example refers to Figure 1.



(BIM by design software - Autodesk Civil 3D & Revit to identify potential site constrain in underground)

Figure 1: *Visualization of potential risks at early design stage for commercial development at Kai Tak*

2.2 Efficiency and Accuracy of Formation Layout

Designing the master layout for a building development is time consuming, especially in utilization of underground space. To reduce cost and time implications of a master layout, cutting and filling can be formed strategically to minimize the amount of excavation and material needed for grading (or backfilling). Moreover, identification of soil & rock conditions is also dictating the layout of basement. In the past, a number of 2D sections would be necessary to identify the soil & rock conditions and take advantage of natural topography for master layout design but that approach is not efficient.

Today we have BIM as a strategic tool to optimize the cut and fill analysis process. This can help (i) to identify areas where excavation and filling can be minimized without compromising the integrity of the site (Figure 2b); (ii) to reduce the construction time in excavation of hard material and (iii) to reduce carbon emissions.

Comparisons of bulk excavation volume for master plan layout design with and without BIM at the early stage of development of several projects are shown below Figure 2a:

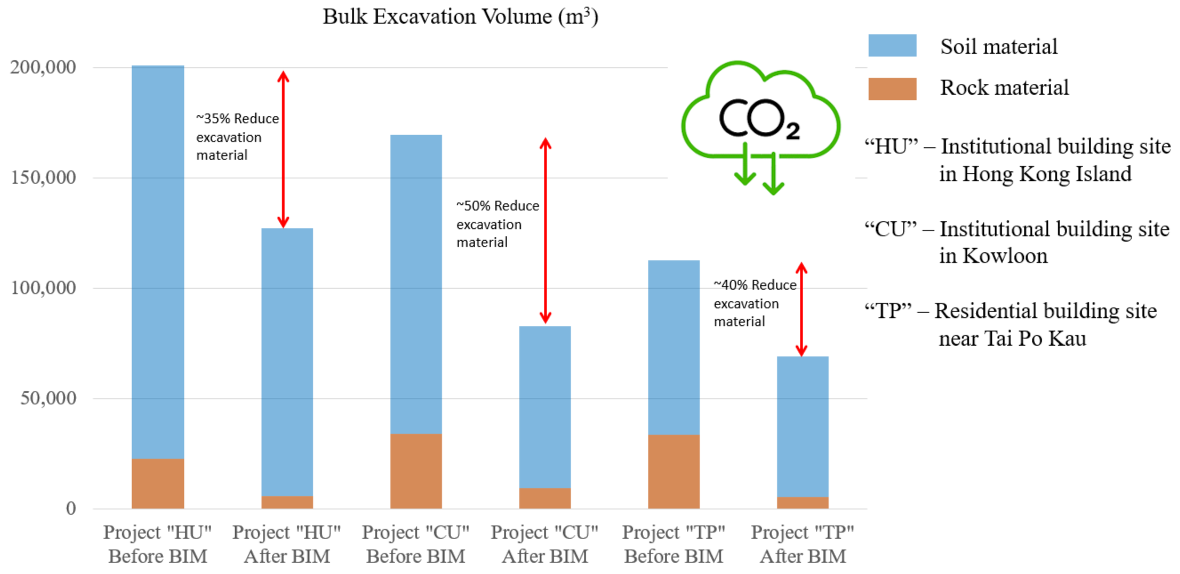


Figure 2a: *Reduce bulk excavation after review master plan layout in BIM.*

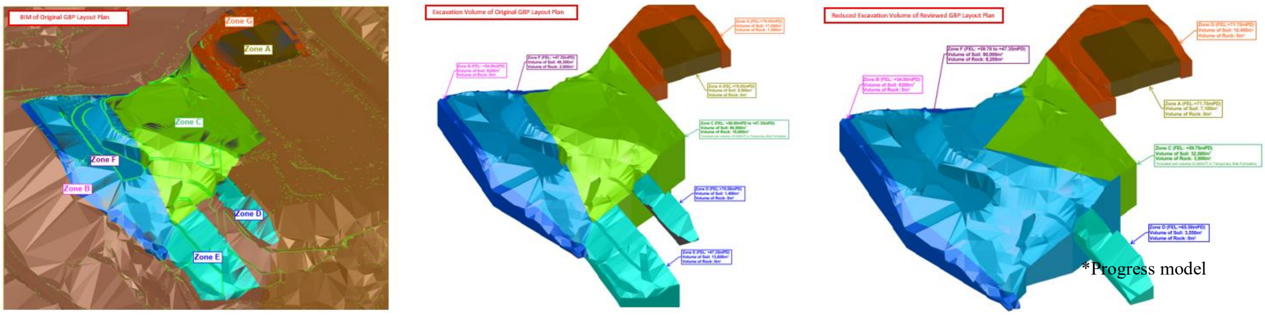


Figure 2b: *Cut & Fill analysis by 3D modeling for institutional building development in Hong Kong Island*

(BIM by design software - Autodesk Civil 3D & Revit to minimize cut & fill during planning stage)

2.3 Management of Geotechnical Data

Good management of geotechnical data can help to improve the assessment quality of potential hazards associated with site geology such as fault zone and sinkholes. BIM is a digital process that can be used for foundation design and geology analysis to improve the accuracy, speed and efficiency of the design scheme selection. For example, the model can help to identify areas of site with poor soil/ rock condition, such as data of fault material encountered in GI records and help to determine the appropriate foundation plan strategy. Example demonstrated in Figure 3.

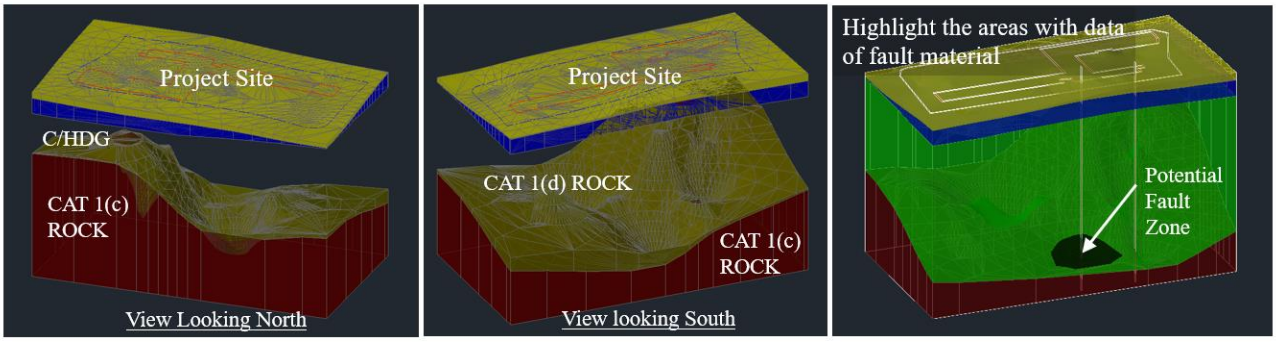


Figure 3: *BIM involves creating a 3D model of site geology for hospital development at a Kowloon site to identify potential fault zone.*

Moreover, it can help to improve the efficiency of design such as clashing analysis, quantifying design elements, and creation of design sections, etc. Example of BIM involvement is shown in Figure 4a and example of BIM application in soil load design is shown Figure 4b.

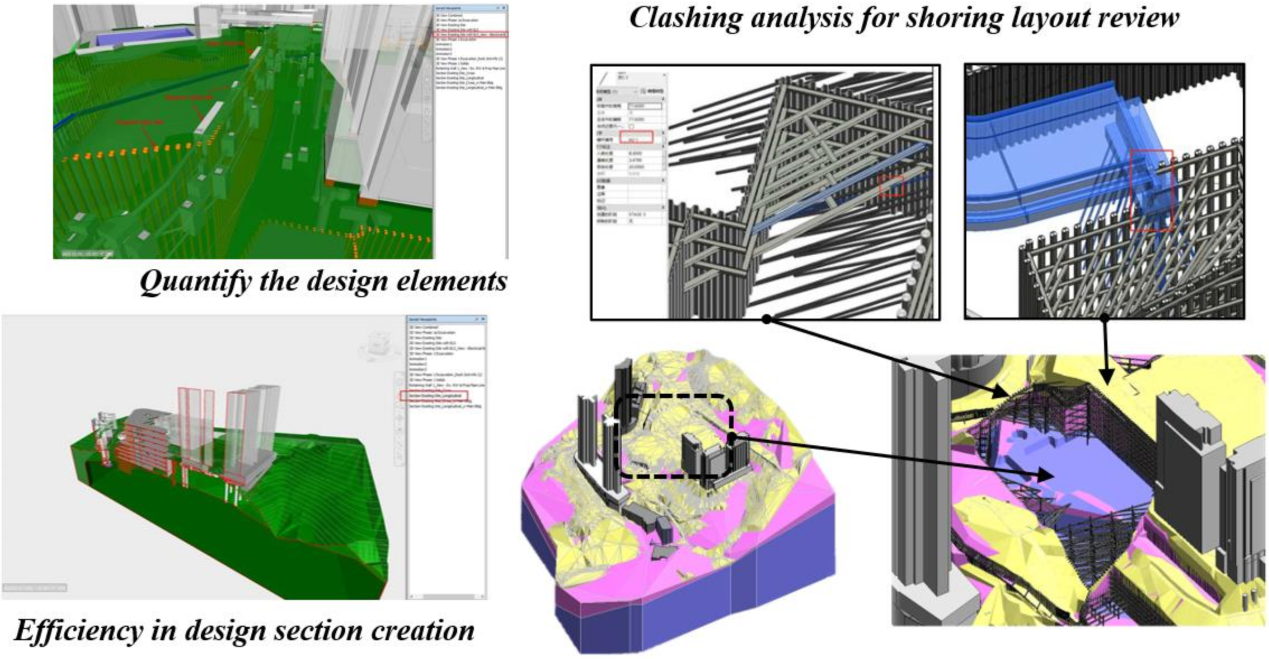


Figure 4a: *BIM involvement in detail design stage for institutional building development in Hong Kong Island*

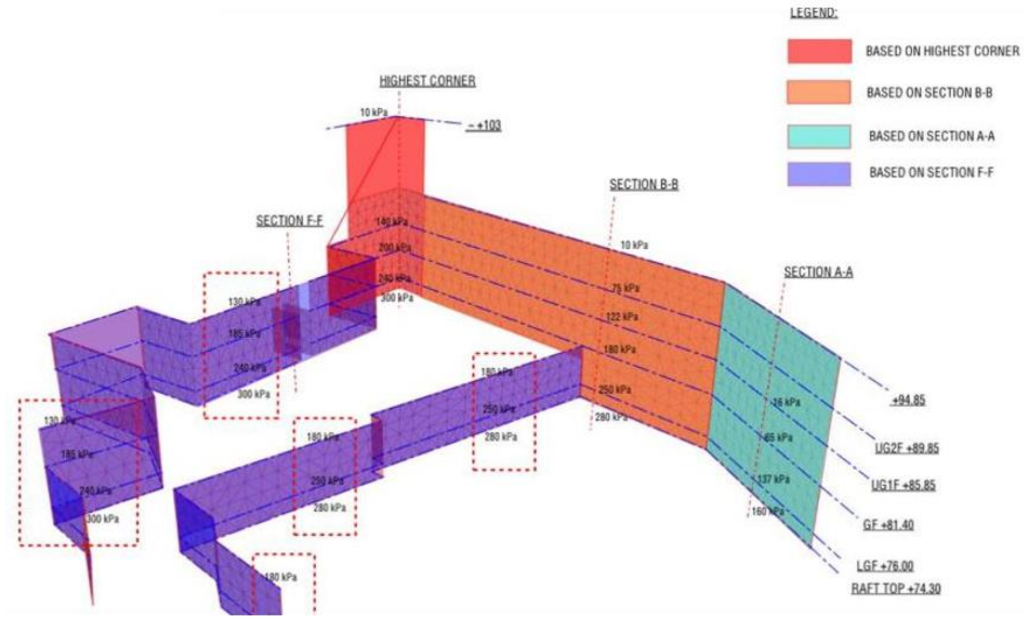


Figure 4b: *BIM involvement in detail design for building soil load*

3 Construction Site Monitoring

3.1 Construction Monitoring

One of the key benefits of BIM for construction monitoring is that it enables the engineer to track progress against a detailed construction schedule. This can help to identify potential delays or bottlenecks early on, so that corrective actions can be taken before the project falls behind schedule. By integrating the models with survey data (i.e., drone with lidar scanner) and tracking material deliveries on site, BIM can help the engineer to optimize the site formation (or foundation and ELS works) programme, estimate construction cost and understand better the construction status. Example refers to Figure 5a.

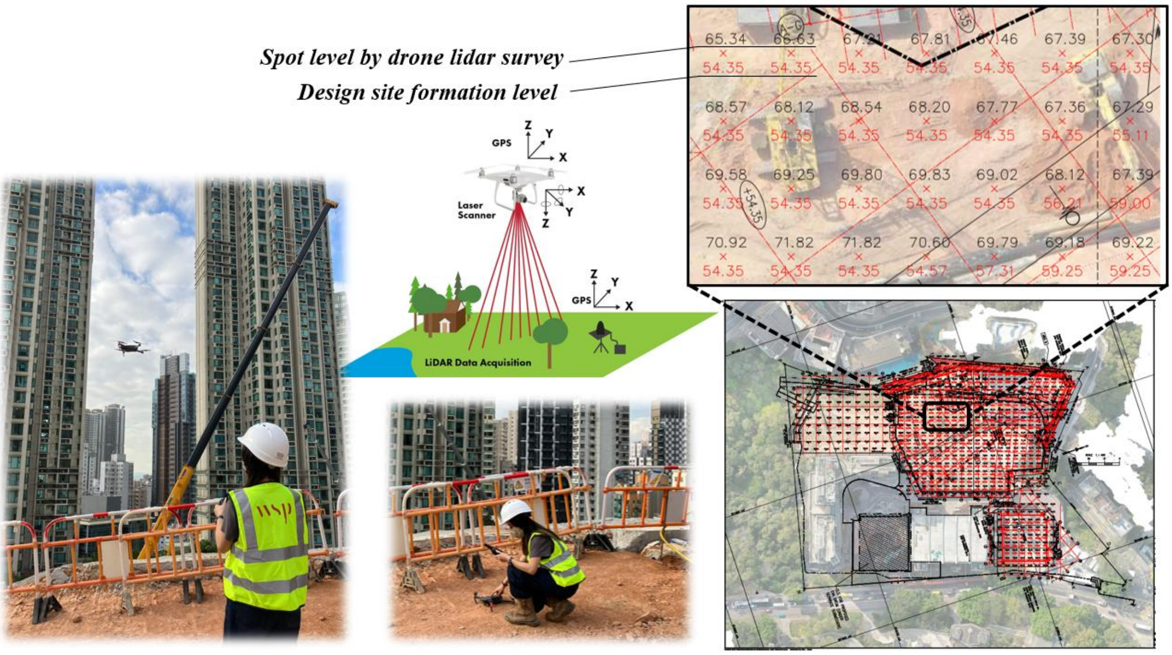


Figure 5a: *Site staff using drone lidar survey data integrated to BIM for construction monitoring.*

Figure 5b: *BIM technology to track the construction progress and cost status.*

Nowadays, creation of the 4D (and 5D) modelling, as shown in the above figures, is one of the BIM uses to improve communication and collaboration among project stakeholders. Example refers to Figure 5b.

3.2 Simulation for Works Sequence

BIM can also be used to optimize construction process by providing a detailed, step-by-step works sequence. For example, it can be used to identify potential conflicts between different elements of construction, such as installation of ground anchor and strut removal sequence and help to find solutions for these conflicts before construction begins. In addition, it is possible to reduce waste, minimize downtime and improve safety on the construction site.

The simulation of construction method in geotechnical works is developed to rehearse construction sequence digitally, which allows the engineers and workers to understand it more before the work begins. An example of BIM for strut removal sequence is shown in Figure 6.

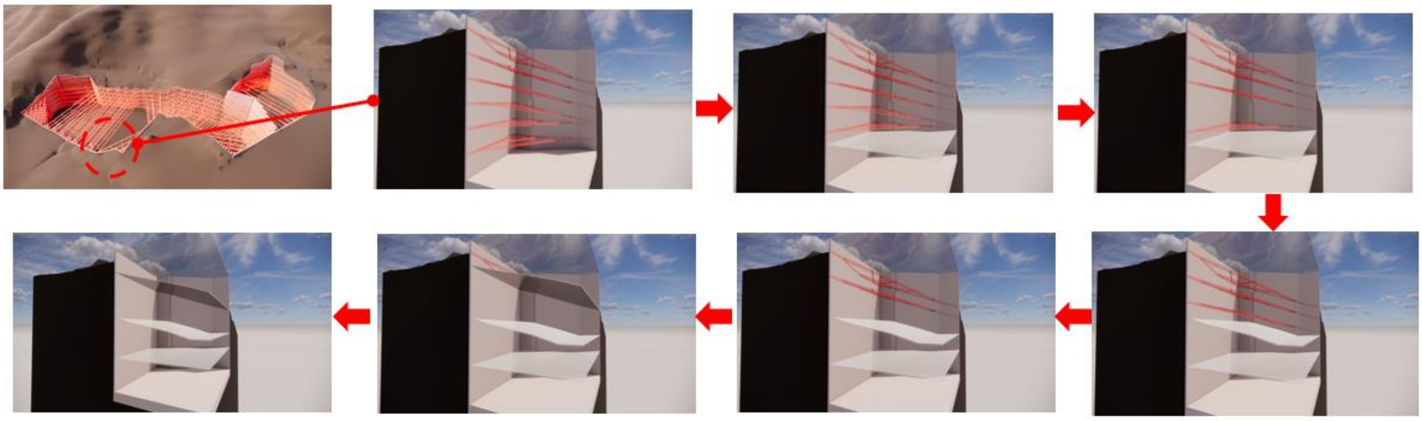


Figure 6: *BIM involvement in detail design for strut removal sequence*

(BIM by design software - Autodesk Navisworks to model ELS de-structing sequence with permanent structure)

4 Conclusions

Using Building Information Modelling (BIM) in geotechnical works can result in several benefits including:

1. Enhancement in the efficiency and accuracy for master planning, especially in sub-structure design
2. Visualization of the geotechnical conditions and structures, which can help to identify potential issues and design solutions.
3. Better management of geotechnical data and improvement of the quality and consistency of the design, Thus resulting with more cost-effective design and improved sustainability
4. Powerful construction monitoring for improving construction efficiency, reducing costs, and helping the projects to be completed on time and to a high standard.
5. Improved communication and collaboration among engineers, contractors and owner.

Down the road, it is expected that BIM technology will continue to evolve and become more sophisticated. This will provide geotechnical engineers with even more powerful tools for creating accurate, efficient, and collaborative designs, and will help to enhance innovation and progress in the field of geotechnical engineering.

5 Declarations

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