Application of BIM in Geotechnics – Case Study on a Deep Excavation Project

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ABSTRACT: This paper presents the application and benefits of virtual design, in particular, Building Information Modelling (BIM), using the case study of an underground basement temporary works design in Jakarta, Indonesia. The utilization of BIM in an underground construction project has led to an improvement in design and construction productivity. As the information can be displayed in a three-dimensional manner, the BIM helps the designer to better understand the complex geometry of the permanent basement structure. This allows the designer to be able to make better informed judgments, in turn producing a more optimised design and speeding up the decision making process. In addition, the BIM enables clear communication among the designers of different disciplines, construction team and also with clients. As the trend for design turnaround time is increasingly shorter, combined with the need to understand more data from different disciplines, it is important to have all the information presented in BIM during design stage. This enables early identification and resolution to potential design deficiency and construction problems, rather than leaving them to the construction stage which would be more detrimental and costly to rectify.

1 INTRODUCTION

In urban areas, where land space is becoming more congested and scarce, utilizing underground space becomes a highly valuable option to optimise the land use and keep up with the pace of development. The challenge in the current trend of underground space construction is to have deeper structures and more complex structural geometry for space utilization. This challenge is compounded with the need to assess the impact of excavation on the ever-increasing presence of existing structures and services in the vicinity. As the industry further develops with more regulatory requirements, there are more available documented data in digital format from the design and construction of the existing structures and services. Having all these information well presented in one medium gives the designer better insight and leads to better informed decision-making when selecting a design scheme for a development.

In current Singapore practice, especially in major infrastructure and building projects, BIM has already been adopted as part of design and construction requirements by the clients and authorities. However, the main application of BIM tends to focus on detecting clashes of proposed permanent works which involves architectural, structural, mechanical and electrical elements. In addition, BIM has also been used by quantity surveyors to calculate the cost of the construction material required. This paper illustrates how BIM can be utilised to aid geotechnical engineers to plan and design for temporary works, which has not been commonly adopted in the industry.

The case study is on a mixed development project located in the heart of the CBD of Jakarta as shown in Figure 1 and is a Design and Build (D&B) project. This case study is selected to demonstrate the successful application of BIM in geotechnical design work in particular for a basement temporary works design.

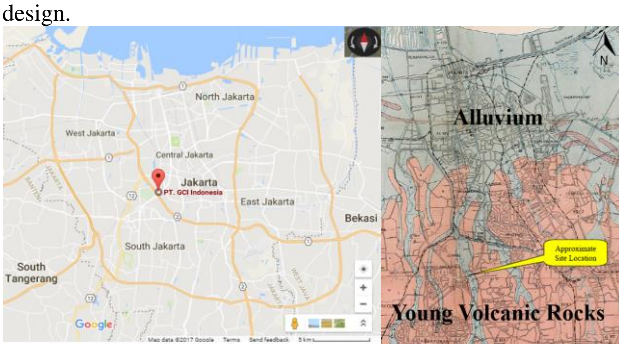

Figure 1: Site Geographic Location on Google Map (Left) and on Geological Map of Jakarta and Bogor area (Indonesia. Direktorat Geologi.; 1969) (Right)

2 CASE STUDY

2.1 *Proposed Development*

The development is approximately 125m by 50m wide and 19m deep; consists of 61-storey tower with 15-storey podium and 4-storey car park basement as shown in Figure 2. The focus of the paper is on the deep excavation design at the podium area where there are two complex sets of ramps.

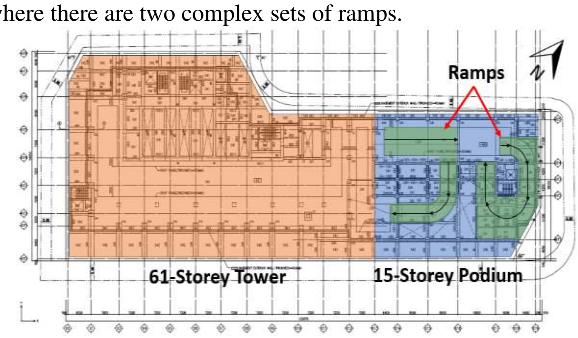

Figure 2: Schematic of Development Layout

2.2 *Ground Conditions*

The geology of Jakarta comprises complex sequence of recent deposits: Holocene deposits (Alluvium), Pleistocene deposits (Young Volcanic Rocks) and Tertiary deposits. As shown in Figure 1, the site is located at the Alluvium area with Young Volcanic Rocks on both sides of the Alluvium.

From the results of ground investigation carried out in early 2016 by the local ground investigation contractor (PT Pondasi Kisocon Raya, 2016), the subsurface profile of the stratigraphy is relatively uniform as shown in Figure 3. The site is generally underlain by Fill, soft to medium stiff silty Clay from river alluvium or Holocene deposit and very stiff to hard silty Clay from weathered young volcanic rocks or late Pleistocene Volcanic Fan.

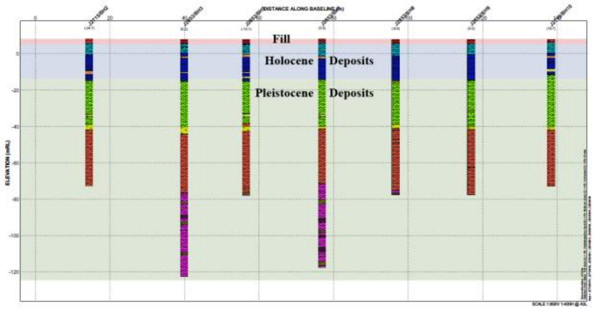

Figure 3: Generalized Geological Profile from West to East

2 .3 *Constraints and Challenges*

The site for the development is located adjacent to high rise buildings and major road with underground MRT tunnel underneath. The design of the deep excavation is governed by the stringent wall deflection criteria of 0.5%H, where H is the depth of excavation.

The basement permanent structure at the podium side consists of a set of sloping floors ramp adjacent to the tower area and a set of helical ramp at the eastern side of the podium. The design of the retaining wall becomes critical depending on the sequence of the removal of the temporary struts and casting part of the ramps, and the relative vertical distance between the temporary struts and permanent lateral structure.

In consideration of the above constraints and challenges, to design for the strutting arrangement and plan the construction sequence within a month, a BIM – Revit model was built to understand the complex geometry of the permanent structure before designing the scheme of temporary lateral support system. The BIM model has shortened the time for the engineers to assimilate all the 2D plan drawings of every basement floor and a number of cross sections drawings to appreciate the complex geometry of the permanent structure.

The project is D&B, fast pace in nature, and requires regular discussions via teleconference by the involved parties based in different international offices with different culture background. The application of BIM has improved the communication for design and construction, hence shortening the workflow cycle and its frequency.

2 .4 *Deep Excavation Scheme*

Considering that the deep excavation is in a relatively softer ground and there is stringent control over ground movement, a robust braced excavation scheme is proposed to be the earth retaining stabilizing structure (ERSS). A permanent diaphragm wall and temporary steel struts are adopted to be the temporary retaining wall and the temporary lateral support elements respectively.

In order to have an optimised design and construction, the permanent structure geometry and behavior in terms of lateral supports are studied before proposing the strutting arrangement and the construction sequence. As the basement ramp is designed for a single threaded helix circulation, the levels of the permanent lateral support on the north, south and east walls are varied as illustrated in Figure 4.

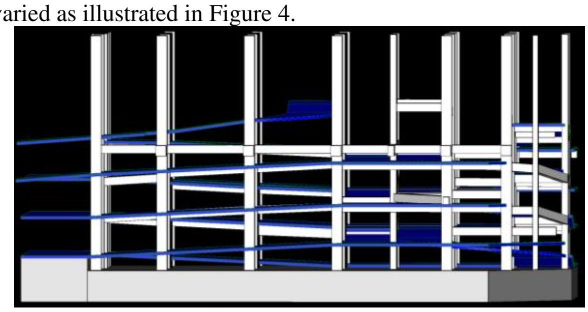

Figure 4: BIM model of Basement Permanent Structure

After a few rounds of design development with the structural engineer and construction team, an irregular strutting arrangement was proposed which has benefit of an independent relationship between the strutting removal stages and casting of the permanent lateral supports scheme as shown in Figure 5. The longer the temporary struts are left in, the smaller the envelope forces on the permanent structure has to be designed for, which reduces construction material costs. With the BIM model, the location of temporary struts can be easily determined to avoid the permanent structure. In addition, the engineer not only can easily communicate this option to the client but also can quickly zone the critical sections and run the minimum number of geotechnical analysis sections to design the ERSS.

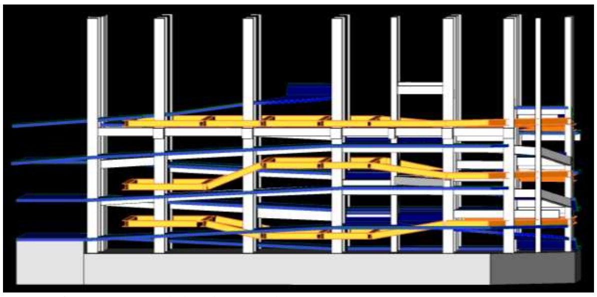

Figure 5: BIM model of Strutting Arrangement

2 .5 *Benefits of BIM*

As illustrated in the above sections, for this project, the BIM model has been a critical technology to improve the overall design and construction productivity. Not only can the engineers quickly decide on the strutting system and construction sequence of the strutting removal stages but also able to make use of BIM to have a macro view of the overall design, identify the critical areas and produce a more optimised design. Moreover, the engineer is able to clearly communicate and discuss the design proposal among the engineers of different disciplines and also with clients. Furthermore, in the process of understanding the behavior of the permanent structure, the engineer is able to detect the clashes between the beam and slab elements of the complicated ramp structure and communicate this issue back to the client at the early stage of the design.

3 POTENTIAL APPLICATIONS OF BIM IN UNDERGROUND DESIGN AND CONSTRUCTION

Besides the applications as described in the above case study, BIM can also be utilised as such: simulate critical stages of the construction sequence in 3D presentation; integrate with Geographic Information System (GIS) to understand the ground conditions of the site; as a centralised database system in managing information for the design and construction; and as a potential asset management tool for the built structure.

4 CONCLUSION

This paper is intended to serve as a project reference of the successful application of how BIM improves the design and construction productivity and aid geotechnical design in deep excavation projects. As demonstrated in this paper, with BIM, the designer is able to manage the project more efficiently while improving safety at the same time. The application of BIM in geotechnics should be further explored and advocated, for the construction industry to cope with the demands of projects of ever larger scale and increasing complexity.

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6 REFERENCES

Indonesia. Direktorat Geologi.; Indonesia. Departemen Pertambangan. (1969). Peta geologi teknik daerah Jakarta-Bogor. Jakarta: Departemen Pertambangan.

PT Pondasi Kisocon Raya. (2016). Ground Interpretation and Foundation Recommendations at Bendungan Hilir, Central Jakarta. Jakarta.