Implementation of Building Information Modeling (BIM) and Geotechnics Safety Analysis Trends in Residential Project

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ABSTRACT

The development of Building Information Model (BIM) in modern times has tremendously aided civil engineers in optimizing and regulating designs, minimizing errors, reducing risk, enhancing accuracy and feasibility, and generally improving projects delivery. In addition, the use of BIM has significantly contributed to time and cost savings. Other advantages include the ability to visualize and analyze data using 3D modeling and relevant engineering knowledge.

Geotechnical data is usually collected at the start of a construction project in order to better understand the subsurface conditions as well as slope stability issues. Soil qualities, slope geometry, groundwater conditions, and geological features are examples of geotechnical investigation data. The presence of geotechnical data has the potential to improve the Building Information Modeling process. As a result, project teams can integrate BIM to improve their grasp of numerous analytical parameters related to slope safety, critical failure surface, and probable failure model by using the data that has been gathered.

The objective of this study is to explore how observing geotechnics data on residential projects throughout the implementation of Building Information Modeling improves safety, cost efficiency, and time savings. This paper examines the case of residential project planning in which the ground surface has elevation differences that cause slopes at several points using the following method: using real data from the field and then analyzing Geotechnics safety using Sted-win, so that the data could be integrated into Building Information Modeling.

With this information, the results of the Building Information Modeling and Geotechnics Safety Analysis implementation demonstrated that the geotechnics and building structure of this residential project are capable of bearing the load by adding piles at several points prone to landslide measures caused by the buildings and earthquakes. Furthermore, the integration of Building Information Modeling and geotechnical data enhanced design and effective communication for project team decision-making.

KEYWORDS: Building Information Modeling, Sted-win, Management, Geotechnics Safety

1. Introduction

The widespread development of Building Information Modelling (BIM) is mainly due to the advantages in terms of cost and time savings of a project and its realization, generated by the reduction of unforeseen problems and the easier updating of the digital model (Magilinskas et al., 2013).

Architectural firms in the US can gain a significant market advantage through the utilization of BIM, as it leads to cost reduction and enhances architectural methodologies. In his research, Gokuc found that Autodesk Revit software is the most popular BIM tool used among US architectural firms. According to the survey results, 99% of the top 500 American design firms use Revit software for architectural design purposes. To take advantage of the BIM process advantages, a sizable portion of these companies have adopted it or are in the process of doing so. Today, a sizable number of people are becoming acquainted with and learning more about the BIM process, with a particular emphasis on how it applies to architecture.

Geotechnical engineering appears to have been neglected despite efforts by other engineering disciplines to adopt BIM technology principles. The dangers related to the geotechnical properties of the soil, according to Vaniek et al. in 2021, are the main cause of this.

There are some ambiguities because the qualities of ground soil vary with location.

This study presents multiple methods for including data on soil parameters in 3D modeling. Data from a residential project in New Taipei City, Taiwan will be utilized to assess the risks and benefits of each option. In addition, several geotechnic safety factor considerations are made in this research using the Stedwin application.

2. Case of Study

One of Taiwan's major cities, New Taipei, is home to a residential development. 16 boreholes were dug at the location 12 meters below the surface to determine the parameters of each soil layer. The boreholes location is illustrated in Figure 1. and investigation's findings are shown in Figure 2.

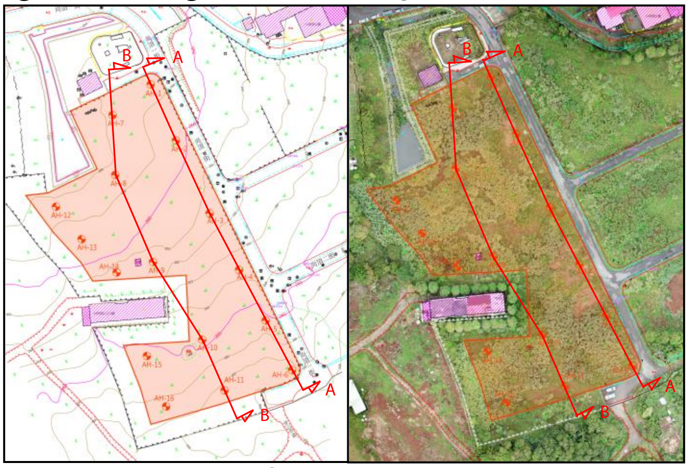

Figure 1. Location of the boreholes in residential project

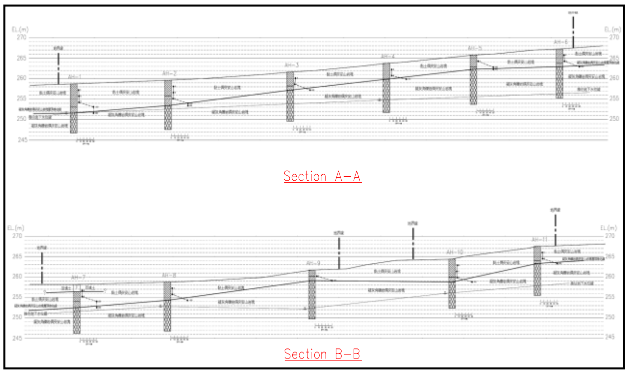

Figure 2. Borehole results

3. BIM-Based Project

Most adopted BIM workflow were using Autodesk tools such as Revit, Infraworks, Civil 3D, etc. A procedure to implement geotechnical data into BIM model divided into several phases:

- Phase 1: Investigate soil properties to make first model of subsurface;
- Phase 2: Analysis of the slope stability with 2 conditions (before and after construction) to know the safety factor;
- Phase 3: Final design based on analysis loading case under the building dead load.

During the initial phase, gather property data utilizing the borehole method at multiple locations within the project area. Subsequently, create a 3D subsurface model using specialized software.

During the subsequent phase, input the subsurface data into different software applications to analyze slope behaviour, conduct simulations for pre- and post-construction scenarios, generate a 2D model, and ultimately export the results as a PDF document.

Once the data subsurface and slope analysis were calculated, the BIM model was completed by integrating the soil surface and reinforcement of the residential project.

3.1. Data Model

Borehole data was used to create a 3D model of the subsurface using the Civil 3D application. This model provides a visualization of the subsurface conditions under the project, including the geographical location, geometry, and soil properties of each soil layer. The subsurface model is shown in Figure 3.

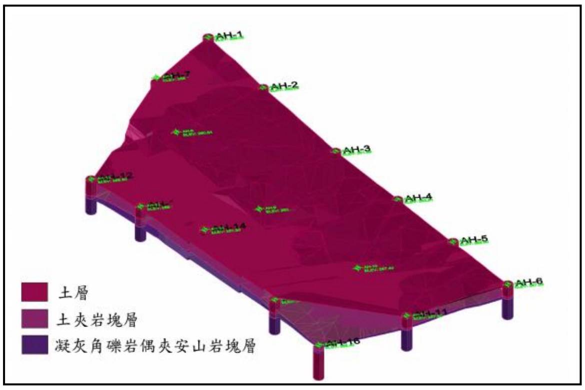

Figure 3. Borehole model of residential project

The following are the advantages of generating a soil model into a BIM platform:

- To manage and update soil data during the site investigation process.
- The 2D stratigraphic profile can be easily generated by another engineer due to its flexible accessibility.

3.2. Geotechnic Safety Factor

Phase 2 consist of input result from borehole data into slope stability analysis application. In this study, Stedwin analysis was used to perform a slope stability analysis. The 2D surface profile and soil properties data were input manually, and the residential load was applied as a load held by the soil. Figure 4 indicate the selected section for slope stability analysis.

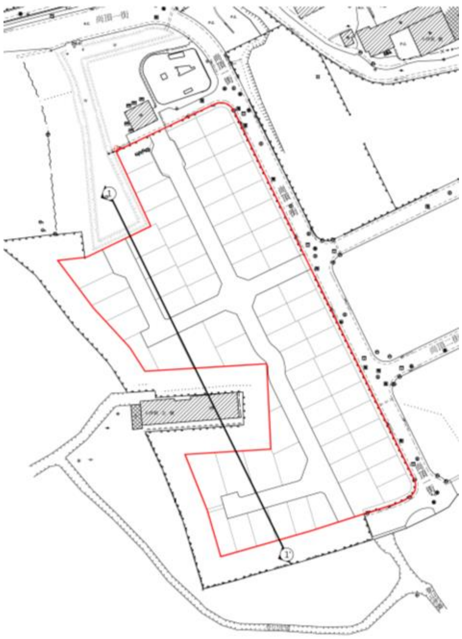

Figure 4. Area of residential project

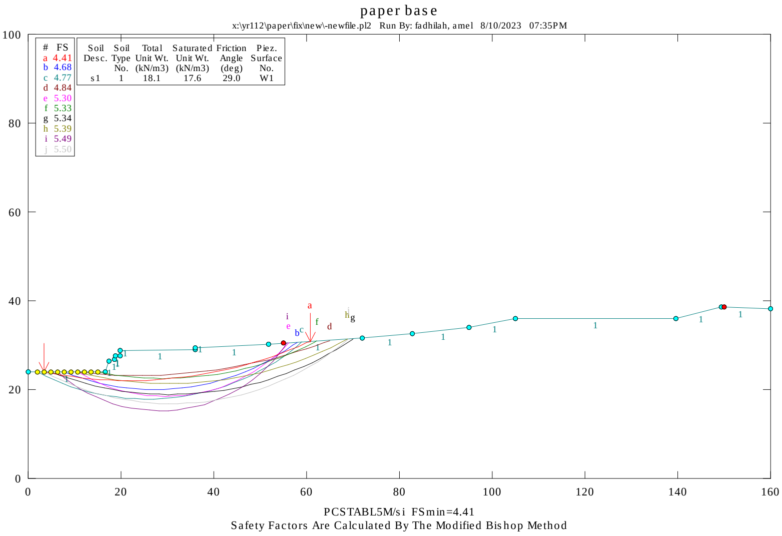

Figure 5. Section profile before the construction

Figure 5 shows a section profile that has already been analyzed by the system. This step can be used to consider two different approaches to analysis: first, using a pile foundation, and second, without a pile foundation. This step can show the difference between the two analyses. The analysis figure result is shown in Figure 6~Figure 11.

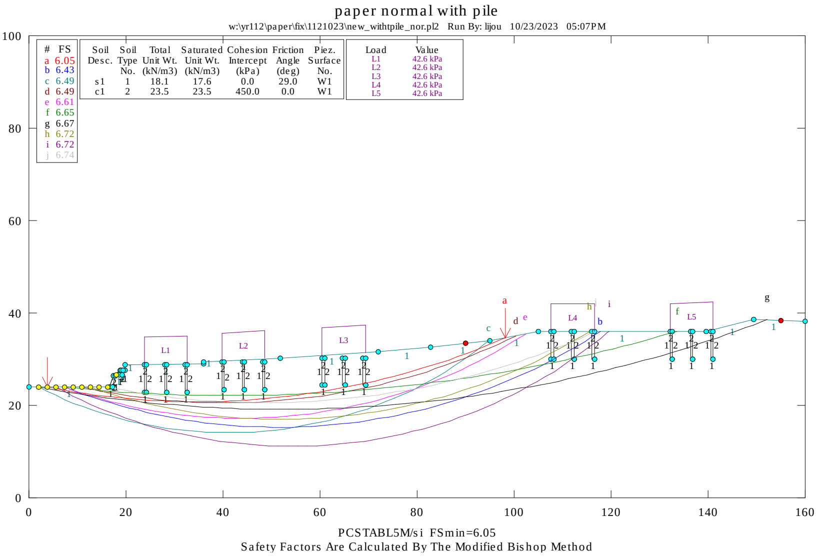

Figure 6. Section profile with pile foundation and residential as load

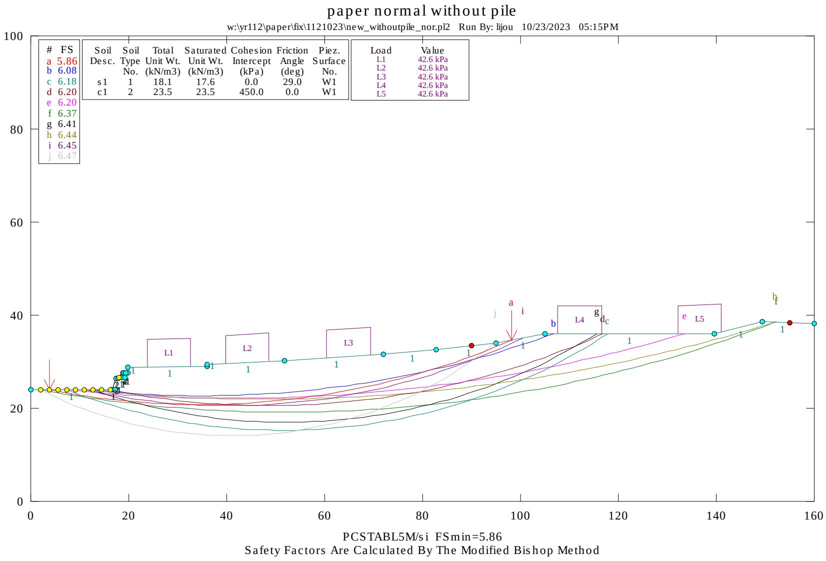

Figure 7. Section profile without pile and residential as load

In addition to the standard situation analysis, this step can be extended to incorporate assessments under earthquake and stormwater conditions, thereby enhancing the safety margins of the slope stability analysis.

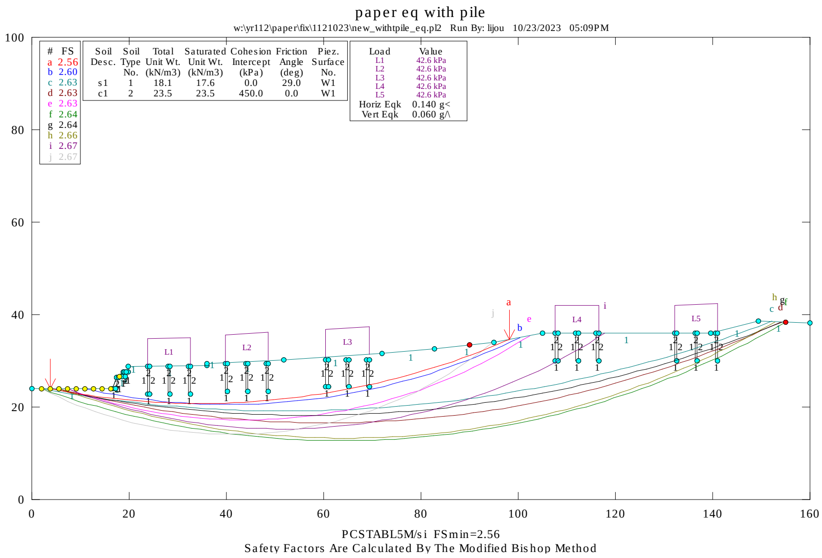

Figure 8. Section profile with pile foundation and residential as a load for earthquake analysis

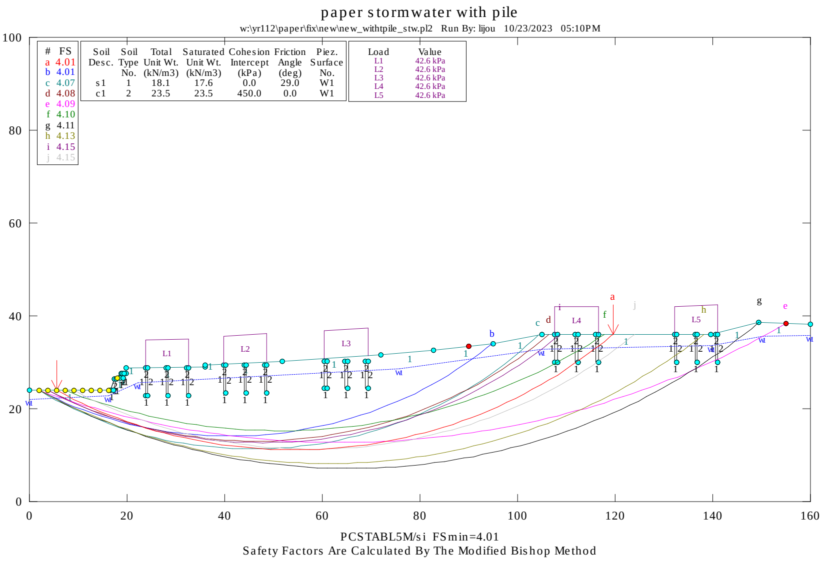

Figure 9. Section profile with pile foundation and residential as a load for stormwater analysis

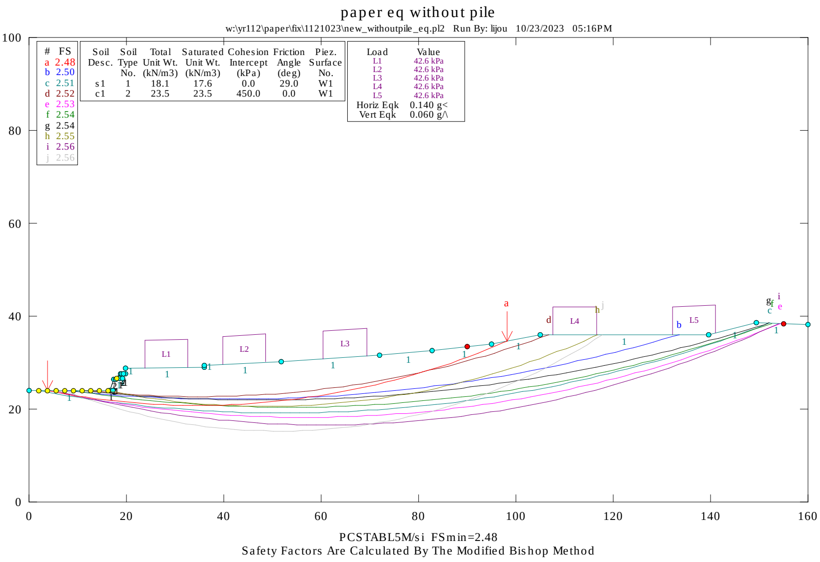

Figure 10. Section profile without pile and residential as a load for earthquake analysis

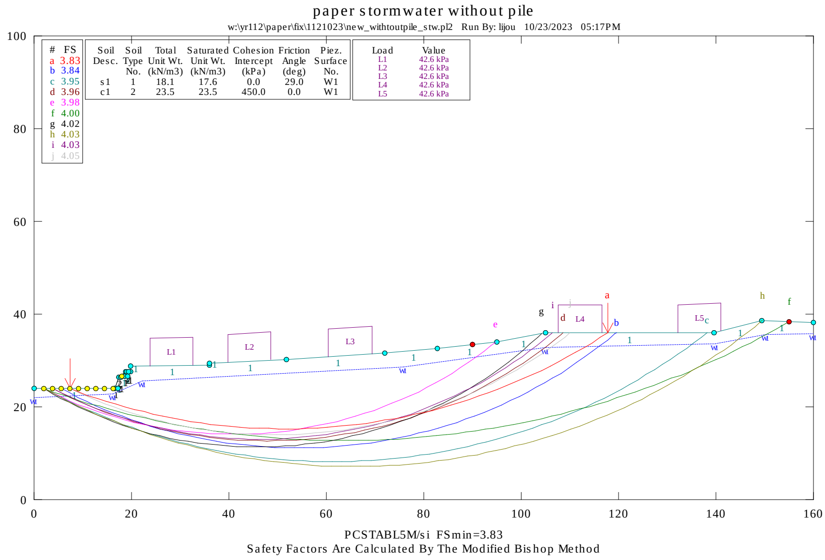

Figure 11. Section profile without pile and residential as a load for stormwater analysis

The analysis result between 2 condition is shown in Table 1. and the design minimum of slope stability analysis based on Soil and Water Conservation regulations and guidelines on Clause 73 shown in Table 2.

Table 1. Comparison of analysis results

Condition	Cases		
	Normal	Earthquake	Stormwater
With Pile	6.05	2.56	4.01
Without Pile	5.86	2.48	3.83

Table 2. Design minimum of slope stability analysis

Stage	Cases		
	Normal	Earthquake	Stormwater
Permanent	1.5	1.1	1.2
Temporary	1.2	1.0	1.1

An analysis of the comparison between the two conditions, one with the implementation of piles and the other without, reveals a significant disparity in safety factors for geotechnical construction. The results of the study clearly show that the safety factor is significantly higher when piles are used. This finding underscores the enhanced safety and stability that pile usage provides during the construction process.

3.3. Final Design

In this stage, the final design is decided and created into a 3D model using SketchUp. The residential design is also imported into SketchUp and combined with the 3D model. The 3D surface from Civil3D is exported in IFC format and imported into SketchUp. The residential design and the 3D surface are then combined to create a complete 3D model. This model can be further refined and rendered to create more realistic visualizations. The final design of 3D model shown in Figure 12 and Figure 13.

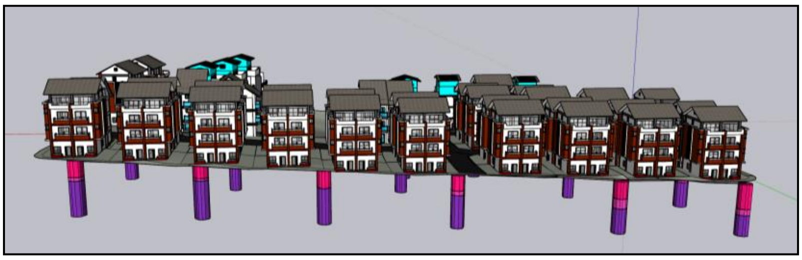

Figure 12. 3D model of the final design in a residential project

Figure 13. Renders result for visualization

4. Result and Discussion

A different method for implementing BIM with geotechnical safety factors is presented in this study. The 3D subsurface is modelled using AutoCAD Civil 3D software with the geotechnical modeler extension, which supports CVS and AGS formats. The modelling process involves collecting data from many boreholes, interpreting the data, and visualizing the results.

After the interpretation of the surface for a section that needs to be analyzed for slope stability. This paper creates 6 different cases to compare between them, with and without a pile foundation for each stage of analysis: normal analysis, earthquake analysis, and stormwater.

In the later stage, the final design can be made after comparing the 6 different cases. It can be modelled as a 3D model using SketchUp software. The 3D subsurface can be imported directly into SketchUp software using IFC format and combined with the residential design. The workflow for this project is visually provided in Figure 14.

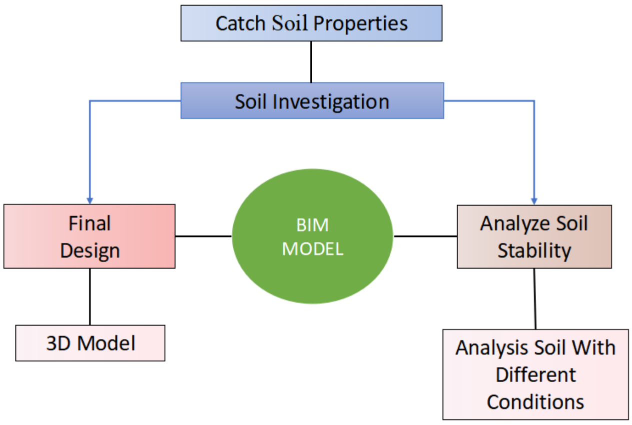

Figure 14. Workflow of the Implementation BIM with Geotechnical Safety Factor

5. Conclusions

This paper demonstrates an application of BIM within the geotechnical sector. One notable aspect of this approach is the 3D visualization of the subsurface. This allows for detailed visualization of subsurface conditions, as well as real-time updates during the project. Additionally, the analysis using slope stability software in different conditions (with pile and without pile) can enhance the safety factor to choose the best conditions for the project. Another benefit is that the model can be easily read or used for a long period of time by the owner if they want to re-examine or revitalization.

5.1 Limitation

The process requires the entry of the results from the Civil 3D software into the Stedwin software, and manual comparison of the data is still required for the conclusion following slope stability analysis.

5.2 Recommendation for Future Studies

Future research should work to improve the methodology so that it can connect automatically between the study of the geotechnical safety factor and the data from the soil subsurface.

6. Acknowledgements

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References

Alaei, A., *Towards BIM Implementation for Geotechnical Projects*, pp. 1-11, 2023.

Berdigylyjov, M., and Popa, H., *The Implementation and Role of Geotechnical Data in BIM Process*, pp. 1-8, 2019.

Esri, *A New Dimension: 3D GIS Brings The Virtual World To Life.2013.*

Gokuc, Y.T.T., Arditi, D., Adoption of BIM in architectural design fifirms. *Achit. Sci. Rev*, no. 60, pp. 483-492, 2017.

Migilinskas, D., Popov, V., Juocevicius, V., and Ustinovichius, L., The Benefits, Obstacles and Problems of Pratical BIM Implementation, *Procedia Engineering*, no.57, pp. 767-774, 2013.

Satyanaga, A., Aventian, G., Makenova, Y., Zhakiyeva, A., Kamaliyeva, A., Moon, S., and Kim, Jong., *Building Information Modelling for Application in Geotechnical Engineering*, pp. 1-19, 2023.

Tawelian, L., Mickovski, S., *The Implementation of Geotechnical Data Into the BIM Process*, vol. 143, pp. 738-741, 2016.

Valeria, N., Roberta, V., Vittoria, C., and Domenico, A., *A new frontier of BIM Process: Geotechnical BIM*, pp. 1-7, 2019.

Vanicek, I., Jirasko, D., and Vanicek, M., Role of geotechnical engineering in BIM rocess modelling, *IOP Conf. Ser. Earth Environ. Sci*, no. 727, 2021.