The use of 3D-geological modelling as tool for project optimization

Patricia Lamas Álvarez[1] Laurence Delplace[2] Laura Benito Broncano[3]
(*1. Amberg Engineering, Brussels,1000, Belgium ; 2. Amberg Engineering, Brussels,1000, Belgium ; 3. Amberg Engineering, Paris,France*)
E-mail: plamas@ambergengineering.com

Abstract: Throughout the design of an underground infrastructure project, changes in initial design are routine. Making these changes and updates fast reduces time and optimizes costs. This is feasible using a 3D coordination model. Creating a 3D coordination model means having a platform that integrates geology information with engineering designs, providing an overview of the whole project.
This paper spells out workflows used to create a 3D geological model and its different applications within a project, using an implicit software that interpolates borehole data. Emphasis is given on how 3D geological models help internal and external collaboration, bringing clarity to complex geology and simple and visual access to data. The advantages and the whole process are showcased based on major European projects.

Keywords: Tunnelling; BIM; Digital 3D modelling; Geology

1 Introduction

Three-dimension (3D) geological models represent a spatial view of the subsurface formations in an observed area. They serve as the foundation for developing a geotechnical design and offer a more precise and thorough depiction of the local geological conditions.
Traditionally, geologists use 2D representations such as geological maps or depth profiles, relying on information from seismic profiles, boreholes, and field observations to illustrate and understand the subsurface of the Earth. The advantage of digital 3D visualization tools opens the door for earth sciences specialists to build new products. These 3D products or 3D models are visually attractive and help specialists integrate various sources of 2D and/or 3D information in rendering new basis of knowledge (Zlatanova et al., 2001).
This paper explains how to build a 3D geological model based on some examples and how they can be helpful in underground projects.

2 3D Geological modelling in the civil industry

Until now, the tools available for 3D geological and geotechnical subsurface modelling mainly aimed at the mining and hydrocarbon industry and often only dealt with specific scenarios and data types.However, as more powerful and affordable hardware and software solutions have become available, their benefits were quickly acknowledged in the civil industry, and their use has dramatically increased.
In city subsurface modelling, any uncertainty concerning the geological conditions is mainly due to the difficulties in obtaining subsurface data and their lack of homogeneity (stratigraphic boreholes, penetration tests, records of drilling parameters, etc.).
Guiding a project to successful accomplishment depends on the quick and correct delivery of reliable information, from analysing the tunnel's geotechnical performance to comprehending the geological environment. Therefore, a tool that clarifies and brings control to a project, with which it is possible to create a digital subsurface built-in with the tunnel underground, can substantially impact the whole project.

2.1 Leapfrog software

The software LEAPFROG WORKS has been used to build the geological models considered for writing this paper. This software uses an interpolation method to create dynamic implicit models. LEAPFROG uses borehole data to build the lithological surface and create the model. The other two essential elements are the area's topography and the boundaries of the model. The borehole information will be subdivided into lithological layers. After the construction of the geological boundaries, the 3D geological model can be produced layer by layer with a solid understanding of the entire geological sequence and the expected geomorphological history of the area under study utilizing the constructed fence diagrams.

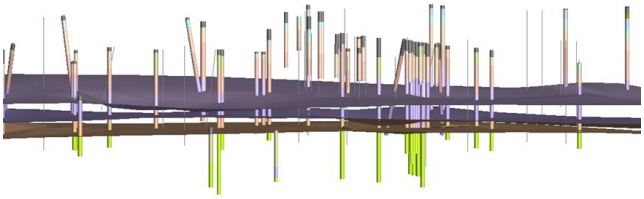

Figure 1. Deposit surfaces
Another crucial factor is the phreatic level, which should also be integrated.

3 Applications and uses of the 3D geo model

As mentioned before, geological models can positively impact underground projects, showing problems that may

need to be more evident in a 2D plan.

The applications explained below is based on the experience obtained when carrying out the model for the extension of metro line 3 in Brussels. The geology is basically formed by clays and sands. Figure below shows a portion of the model with one of the stations that compose the project.

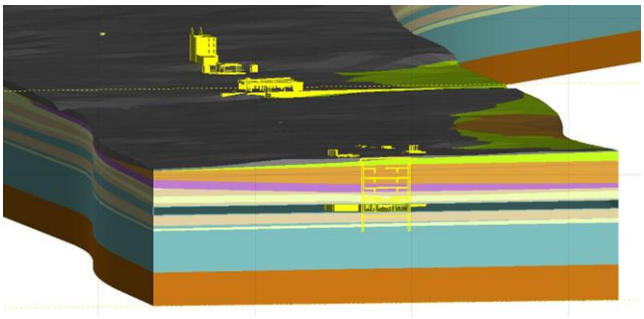

Figure 2. Extract of the Brussels metro geological model

Using as a reference this example, some applications will be listed and briefly explained.

- Longitudinal profile: it is essential for every project, and the model allows exporting an accurate profile
- Cross sections: making them longitudinal, perpendicular, or any direction is possible. They are a vital part of calculations and design analysis. The model provides all sections an added value, especially in projects where the geology is more complex, and a section along the alignment is not representative of the hole surface. It also allows to include all the designs imported in the software, such as the tunnel or the stations, the borehole, and other geotechnical information available.
- Volume excavation: a valuable tool. It can determine the total volume of material that will be excavated as part of the tunnelling boring process. Intersecting the geological model with the tunnel design, the volume excavation will be generated (figure 3).

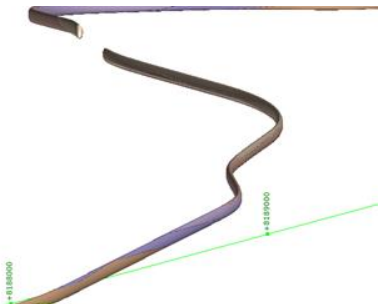

Figure 3. Extract of the Brussels metro geological model

4 Conclusions

Building a geological model for an underground project is easy and relatively fast if all borehole information is available digitally. Still, a model can be done even if it is not the case.

This tool brings many advantages and allows for a huge positive impact. It helps to identify geological risks and brings the possibility to extract much information that helps to do other tasks such as calculations or volume excavation. All this process can be updated easily and quickly, reducing costs and time needed. In addition, it is an excellent way to bring clarity to a project, share information with co-workers, and provide stakeholders at all levels with the information they need to make wise decisions

Acknowledgments

We would like to thank all our clients and partners for the fantastic collaboration on this challenging project.

REFERENCES

Calcagno, P., Courrioux, G., Guillen, A., Fitzgerald, D., & McInerney, P. (2006). How 3D implicit geometric modelling helps to understand geology: the 3DGeoModeller methodology. In XIth International Congress, Society for Mathematical Geology (p. 27).

De Rienzo, F., Oreste, P., & Pelizza, S. (2008). Subsurface geological-geotechnical modelling to sustain underground civil planning. Engineering geology, 96(3-4), 187-204.

Kessler, H., Mathers, S., & Sobisch, H. G. (2009). The capture and dissemination of integrated 3D geospatial knowledge at the British Geological Survey using GSI3D software and methodology. Computers & geosciences, 35(6), 1311-1321.

Kessler, H., Turner, A. K., Culshaw, M., & Royse, K. (2008). Unlocking the potential of digital 3D geological subsurface models for geotechnical engineers.

Zehner, B. (2020). On the visualization of 3D geological models and their uncertainty. Zeitschrift Der Deutschen Gesellschaft Für Geowissenschaften, 172, 83-98.

J.-L. Mallet, Geomodeling, Applied Geostatistics Series, Oxford University Press, New York, NY, USA, 2002.

Zlatanova, S., Rahman, A.A. and Pilouk, M. (2001) 3D GIS: current status and perspectives, Proceedings of the Joint Conference on Geo-spatial theory, Processing and Application, 8-12 Juillet, Ottawa, Canada, 6p.

Perrin, M., & Rainaud, J. F. (2013). Shared earth modeling: knowledge driven solutions for building and managing subsurface 3D geological models. Editions Technip.

Doan, D., Ghaffarianhoseini, A., Naismith, N., Zhang, T., & Tookey, T. (2019). What is BIM?: a need for a unique BIM definition.