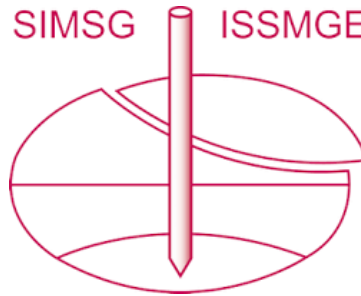


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GeoBIM - a tool for optimal geotechnical design

Mats Svensson

Geotechnical department, Tyréns AB, Sweden, mats.svensson@tyrens.se

Olof Friberg

Tyréns AB, Sweden

ABSTRACT: The geotechnical toolbox includes approximately 200 field methods, not mentioning any laboratory methods. The commercial softwares used for presenting, analyzing and visualizing the data and the models are at least as many. There is a lot to do to be able to seamlessly combine and integrate all data types and interpreted models, most obvious in large infrastructure projects. Data formats and databases for geotechnical data needs to be further standardized and developed. In this article one possible methodology, including technical solutions, is suggested, the GeoBIM concept. The GeoBIM concept is implemented in a number of large infrastructure projects in Sweden, i.e. ESS (European Spallation Source), East link high speed train link (OLP4) and Norrbotten railway link. GeoBIM enables a closed digital loop from field to 3D geotechnical models. To reach the full potential of the GeoBIM concept it should be accompanied by uncertainty models, which is also discussed in this article.

RÉSUMÉ : Les méthodes géotechniques comprennent environ 200 techniques d'investigation de terrain, sans mentionner les techniques de laboratoire. Il existe tout autant de logiciels commerciaux utilisés pour présenter, analyser et visualiser les données et les modèles. Un travail poussé est nécessaire afin de combiner et d'intégrer de façon adaptée tous les types de données ainsi que les modèles interprétés, un impératif dans les grands projets d'infrastructure. Le développement approfondi ainsi que la standardisation des formats de données et des bases de données géotechniques est donc indispensable. Cet article présente une méthodologie possible, le concept GeoBIM, ainsi que des solutions techniques. Le concept GeoBIM est mis en œuvre dans un certain nombre de grands projets d'infrastructure en Suède, parmi lesquels la ligne de train à grande vitesse Ostlänken (OLP4) et la liaison ferroviaire Norrbotten. GeoBIM permet une boucle numérique fermée entre les investigations de terrain et les modèles géotechniques 3D. Pour atteindre le potentiel maximum du concept GeoBIM il doit être accompagné de modèles d'incertitude, ce qui est également discuté dans cet article.

KEYWORDS: GeoBIM, Geomodelling, underground infrastructure, visualization, geotechnical database

1 INTRODUCTION.

The everyday mission for the geotechnical engineer is to find out and in the best possible way define and describe what the underground is like, i.e. mechanical properties and geometry, sometimes called geotechnical modelling. In this work a lot of data is handled and many different software is used. One of the biggest challenges is to make use of all the data during the interpretation and the modelling. The traditional way includes a lot of drawings, plots, diagrams, tables spread on desktops, walls, floors, screens etc. In the digital world that has been evolved during the last 30 years, a lot of new opportunities for joint interpretation has opened up. The GeoBIM concept suggests how to make use of these opportunities available today, state of the art geotechnical data handling and workflow.

2 USE OF GEOTECHNICAL DATA

The geotechnical data is used in a number of purposes along its road to the archive for long time management. The different stages could be separated as:

- Storing data (during project)
- Modelling
- Designing
- Visualizing
- Data management (long term / archiving)

2.1 Storing data

In an ongoing large project data is delivered on a more or less regular and daily basis and the geotechnical model is

continuously evolving in the same pace. To be efficient, get the most out of the data and keep up the quality of the geotechnical model, it is most necessary to have a clear and convenient strategy for data import, QA, storage and data access for all project members. Hence a comprehensive database is crucial. Since the number of field and laboratory methods used can reach over one hundred and there is lack of data format standard, the number of different data formats is large, and immediate joint interpretation becomes a challenge. Therefore, in order to handle all available data a database has to be generic yet able to handle very detailed information regarding method specific parameters. Furthermore the database model must be flexible in order to handle information from new types of field and laboratory methods in order to serve over time. Last but not least the database also needs to be accessible for all project members in need of geotechnical data, regardless of organization or company affiliation since complex infrastructure projects involve several different actors.

2.2 Modelling

A large number of tools for geotechnical modelling are available – from xls-algorithms via CAD (Civil3D, Novapoint, Microstation) to the most sophisticated software in the mining and petroleum industry (GoCAD, Micromine), see Figure 1. For an efficient workflow and to keep up the QA a flexible database is crucial in communicating with any modelling tool. Today often coordinate transformations, data format converting using scripts etc. has to be carried out in order to get different data sets into the same software for joint interpretation and modelling. During this process there is a risk for mistakes and misprinting. Not to mention an inefficient workflow.

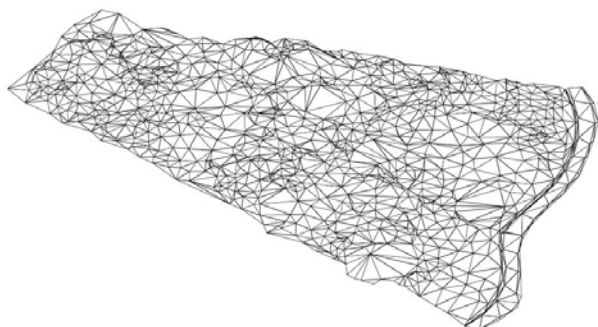


Figure 1. Geotechnical model showing a bedrock surface created in CAD design software.

2.3 Designing

At different stages during the design process geotechnical models (at continuously improving resolution) is delivered to the design staff – road, railway, bridge, tunnel etc. - in order to at all times have the most updated geotechnical conditions available for design of foundations, handling of settlements etc. Those design disciplines most often use design software of CAD-type. For an efficient workflow this requires that the geotechnical modelling tools can communicate with the design software. For QA purposes it is also powerful if all sounding and sampling data can be visualized in 3D in the design software, see Figure 2. This again requires data formats capable of communicating with each other. Today this is not always the case.

In order to work according to a BIM vision within an unbroken digital information supply chain the geomodel and its objects need to be delivered to the design departments in a format which they can instantly use too steer their design. The information process should therefore be streamlined for a number of different tasks which requires information interpreted and evaluated by geotechnical engineering expertise.

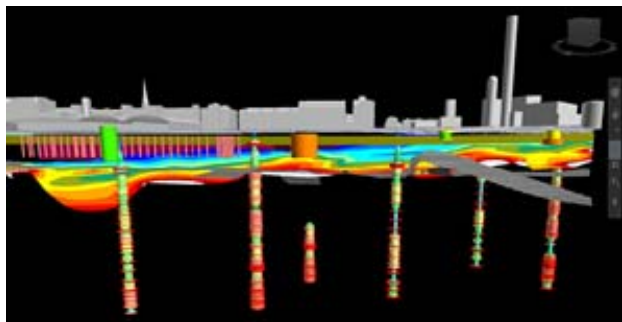


Figure 2. Geotechnical data from many different methods are visualized together with the current tunnel design and parts of the existing structures (ArcScene GIS software).

2.4 Visualizing

Traditionally geotechnical and rock mechanical engineers, geologists and hydrogeologists are the technicians working with the geotechnically related data, reporting the final models in 2D on drawings and in written reports for further use in the design process. These models seldom reach the full potential in terms of how much value there is in the geotechnical model. With modern tools much more can be gained from the geotechnical models, at all stages of a project, and by this supporting the whole design process in a better way than today, aiming at a more optimized project as a whole. By using modern

visualization tools (3D) a larger group of stakeholders/actors can be engaged/involved, the geotechnical model can be communicated in a pedagogic way and better and more optimized understanding and design can be gained, see Figure 3. In large projects communication (and e.g. groundwater management) is the key factor for success.

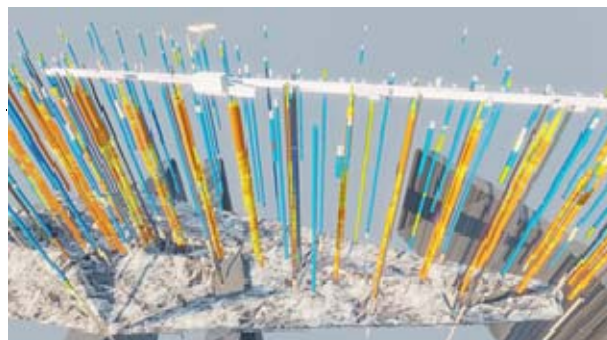


Figure 3. A geotechnical 3D model visualized together with core drilling data and parts of the current design of the facility in a software using computer game technique to get photo realistic images. A powerful tool to communicate a geotechnical model. /Svensson M., 2015)

2.5 Long time data management

The design and building process has different time schedules in different parts of the world. In Scandinavia processes of 20 years from political decisions of large infrastructure projects until they are ready to use, for example until a road is opened, is not uncommon. Even longer processes from the first field work to the start of the digging exist. To be added is a required designed lifetime of the bridge or road of 120 years. During this period (20-140 years) methods, data formats, interpretation software etc. develop and improve a lot, whereas the geotechnical conditions change very little. Hence data collected long ago is always interesting, using the most updated technique and theory. However, management of geotechnical data can improve a lot, both within projects (even between different phases), and in organizations and authorities (for example governmental road administrations) continuously ordering geotechnical investigations. In order to do this a proper database and an efficient import and export workflow is needed. In Figure 4 the principle use of geotechnical data during a project is shown.



Figure 4. The rise and fall of geotechnical data.

3 WHY BIM UNDERGROUND?

The principle of BIM – Building Information Modelling – has been used for structures above ground for more than 15 years. Why not in geotechnics and underground? The reason is that, in comparison with the building industry where the material properties and the geometry of the objects that are put

together is known, including classification systems (for example CoClass, Uniclass, Omniclass) etc., in geotechnics none of these are known before the field work is carried out. Both the material and the geometry of the underground has to be defined before even the smallest idea of creating a GeoBIM model can be taken into account. Discussions on using underground geotechnical objects and classification systems has hardly begun but could in the future help us bring order to the underground.

However, in Sweden the large infrastructure projects now require that also the geotechnical model and the geotechnical data is incorporated in the BIM concept, aiming at reaching a complete 3D digital model of the whole project, including all engineering disciplines.

4 THE GEOBIM CONCEPT

The core of the GeoBIM concept is a database capable of handling - importing, storing, exporting – all geotechnically related data that is used in underground infrastructure projects, hence including data from geotechnical sounding and sampling, rock cores, surface and borehole geophysics, laboratory tests, groundwater and contaminated soil investigations. In addition the GeoBIM concept has closed the digital loop by enabling data to be digitally collected and seamlessly transferred through the whole design process without any manual transformations etc, see Figure 5. However, QA checkpoints are available in the system.

4.1 The database configuration

Essentially the database store point information with location and eventual relation to other points. The point carries a value and this value is related to a measurement (information of measurement method etc.) as well as a dimension (what has been measured). This approach ensures that information from new methods may easily be added and large amounts of data can be handled rationally. The database model is implemented in a PostgreSQL database located in the Cloud.

4.2 Database access

In order to access the information a database viewer and a web map has been connected, which are accessible through a GeoBIM Portal where project members can login to their projects. This enables the project member to get an overview as well as a detailed view of the data and related documents, e.g. seismic profiles.

From within the GeoBIM Portal project members are also able to import data from investigations and export data in various data formats depending on the task being performed and the softwares used. As an example a project member responsible for the geotechnical modelling might be interested in all geo data which can improve the interpretation of a rock surface model meanwhile a geochemical engineer might want data in order to analyse a pollution propagation. The output from both these tasks are then used combined with raw field data in a BIM model in order to review and share the results.

When geomodels are produced by skilled staff making use of all available data and reviewed by cross discipline experts so their interrelationships seems correct then a best possible interpretation has been performed. These models may thereafter be used for a best possible design and best possible quantity calculation etc.

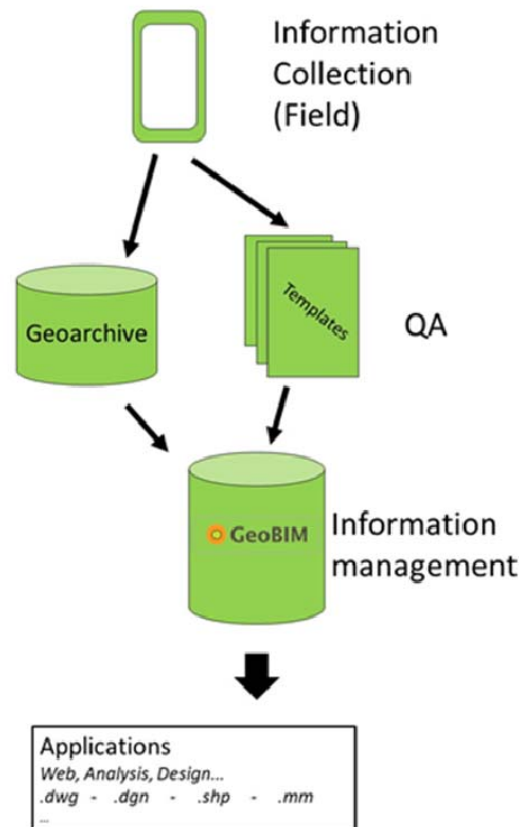


Figure 5. The GeoBIM concept allows data to be collected digitally in the field and transferred through the geotechnical process without any manual transformations, corrections etc, with the GeoBIM database being the core of the concept.

5 IMPLEMENTATION

The GeoBIM concept has been successively developed during 2013-2016 in close collaboration with ongoing projects aiming at reaching gradual implementation. By following an ongoing project on a daily basis it was recognized that the database has to be flexible in order to quickly add new methods. By collaborate with a few different projects also the data format requirements depending on different design tools were recognized, mainly affecting the export formats from the GeoBIM database.

The GeoBIM concept has been used in four major infrastructure projects in Sweden; Varberg railway tunnel, Tvärförbindelse Södertörn, East link (OLP4), Norrbotniabanan. It has also been implemented as the geotechnical data management system in two municipalities and one regional administration in Sweden during 2016.

6 UNCERTAINTY MODELS

As shown above it is now possible to deliver 3D geotechnical models in an efficient workflow, and they even look photo realistic, and very soon there is a chance we will walk around in the 3D model using VR helmets etc. in meetings. There is however a paradox. At the same time this is a chance for the geotechnical engineer to reclaim the underground models and increase the geotechnical impact

on the infrastructure design process. However, there is also at the same time a risk that the model is believed perfectly mirroring the underground. Hence it is important to be very obvious and explain that before digging the model is just an interpretation and a model of the underground. There are still uncertainties.

The good news is that these uncertainties can be handled with various geostatistical techniques, and by that supporting the geotechnical models to become a powerful unity. In Figure 6 an example of a geotechnical model accompanied by a basic uncertainty model is shown.

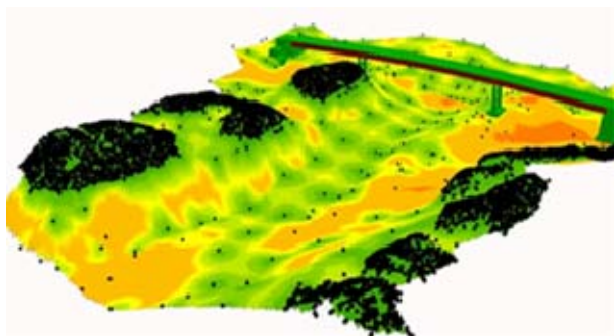


Figure 6. A geotechnical model, the bedrock surface in Project Bypass Stockholm, accompanied by a basic uncertainty model – green meaning <1 m uncertainty and red >10 m uncertainty. Figure from (Wenander K., Båtelsson O., 2015)

Most people in a project know there are always uncertainties, however most often not exact how big or small they are. Control of the uncertainties regarding the geotechnical model (geometry and mechanical properties) continuously during the project has many positive effects:

- Less stress in the project team
- Possibility to plan and optimize the investigation program after the current uncertainty map – “where do we need to fill in?”)
- Risk sharing between different parts in contracts
- Less claims

7 FUTURE WORK

The GeoBIM will continuously be implemented in projects of different size aiming to improve the workflow. Most prioritized is to develop a robust uncertainty model covering both the geotechnical properties and the geometry of the geotechnical model. Parallel to the GeoBIM project presented above a sister project studying uncertainties in geotechnical properties (Müller R. et al, 2014; Prästings A. et al., 2016) has developed promising models and tools for determining the uncertainties of certain parameters, for example shear strength in soft clay, using for example MVA technique (MultiVariate Analysis). Those models will be merged into the GeoBIM concept. The models can for example define the number of complementary investigations that are needed depending on what level of uncertainty that is sought, and hence help optimizing the field program. The second kind of uncertainties, the geometrical, will also be prioritized at the same level. Interesting work on this topic is for example produced by (Wellman, J. F. 2010).

The vision is to develop a GeoBIM concept capable of making maximal use of an optimized investigation program, and in a completely digital workflow deliver a geotechnical model that also is accompanied by uncertainty models for both the geometrical features (surfaces, volumes, lines) and the mechanical properties. Those models will be live from the first day in a project.

8 SUMMARY

Today a lot of different methods (>100) delivering data in many different data formats are used. To make optimal use of all data a proper database and an efficient workflow is needed. The GeoBIM concept suggests such a tool and process, capable of efficient digital handling of all geotechnical data from field to long time management. The end user will be able to access data via web inlog and a map interface. The core of the concept is the GeoBIM database, from which data can easily be exported for 3D modelling etc. It has been recognized that the 3D models have to be accompanied by uncertainty models to reach the full potential of the GeoBIM concept.

9 ACKNOWLEDGEMENTS

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