GeoBIM for optimal use of geotechnical data

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ABSTRACT
The GeoBIM concept is presented. The GeoBIM concept connects the geotechnical phases data storage, geotechnical modelling, design, visualization and archiving. In order to increase quality assurance, efficiency and optimization of the geotechnical field work, a new database capable of handling all types of geo related data has been developed. With the GeoBIM database being the core of the whole concept, tools for seamless communication with geotechnical 3D modelling tools, design tools, visualisation tools etc have also been developed. The GeoBIM concept have been developed and pilot tested in cooperation with a few large infrastructure projects in Sweden during 2014-2015, i.e. the ESS project in Lund and Varberg railway tunnel. The concept will be implemented in project Ostlänken during 2015-2016. Examples from these projects will be shown. By using the GeoBIM concept a more efficient and quality assured geotechnical model than before have been communicated continuously through the projects. The GEoBIM delivery also gives the opportunity to preserve the data and the geotechnical model for the next phase of the projects and for future in the area in general.

Keywords: GeoBIM, visualization, 3D-modelling, geotechnical, database, TRUST

1 INTRODUCTION

The concept BIM is today more or less used on a regular basis in the building industry above ground, at least to a youngster level. When it comes to underground data and facilities the BIM concept is so far however far from up and running. It is shown in a number of ways, i.e. bad archiving of geotechnical data and lack of tools handling more than a few geotechnical data types. The effect of this is that a lot of investigations are carried out in areas already investigated, it is hard to do an optimized interpretation using results from a number of data sets/methods etc. The central drawback is the lack of a common geotechnical data format, and a general database that can keep good order of all geotechnical data that is produced. Such a database would be the core of a GeoBIM concept. These thoughts were described in an R&D GeoBIM application and resulted in a grant from the Swedish Reseaerch Council (Formas) and Sven Tyréns Stiftelse 2012.

The GeoBIM project was formed and are developing the GeoBIM concept 2013-2016, a cooperation between Tyréns and the department of Soil and Rock Mechanics at Royal Institute of Technology in Stockholm (KTH). The project is run under the TRUST umbrella (www.trust-geoinfra.se)

2 WHAT IS GeoBIM?

The GeoBIM concept consists of the five elements below.

- Data storage (incl input/output)
- Modelling
- Design work
- Visualization
- Uncertainty model

See also Figure 1. If the concept is well developed it is rather a communication tool for explaining geotechnical data and models than a pure engineering tool.

2.1 Data storage (incl input/output)

Proper data handling, including coordinates, and a general enough output data format to be used as input for the geotechnical modelling and design tools is the foundation for the GeoBIM concept. In a large infrastructure project geo related data from approximately 100 different methods has to be handled. Of course the optimal interpretation of the geo model would then be if one could make use of all data in the same tool. This has not been the case in any of the available modelling tools on the market. The reason for that is the lack of a standardized data format, many data formats are instrument/manufacturer specific. Hence, in the GeoBIM project the main focus has been to develop a database capable of importing all geotechnical data formats and transforming them to a standardized/general data format which seamlessly can be used by all the geotechnical modelling and design tools on the market, see Figure 1 and Figure 2.

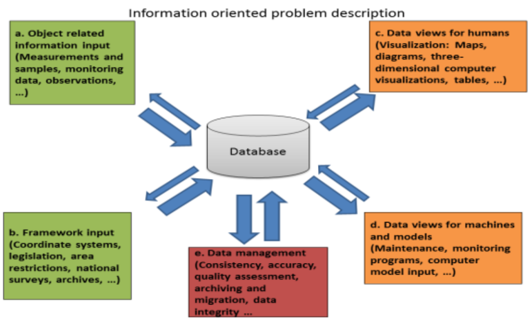
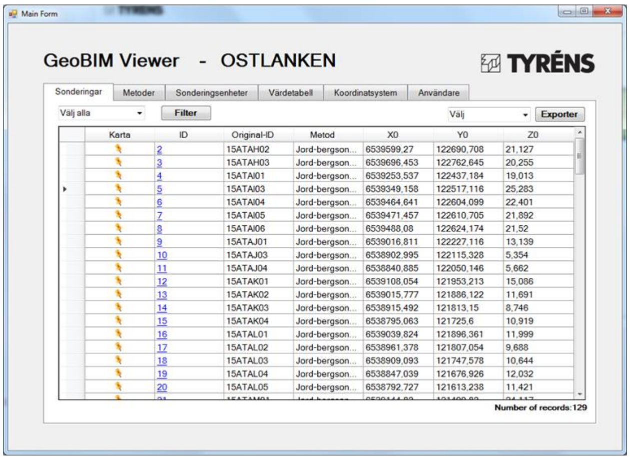


Figure 1 Principle of the GeoBIM database. Import of data from the left (green) and Export of data to the right (orange). The red box illustrates an uncertainty model tool connected to the GeoBIM concept.

The GeoBIM database now developed imports all relevant geotechnical data (approx 100 methods) accompanied by x,y,z coordinates. In case data from a method not available in the database is delivered the method could be conveniently designed for import with a specific tool. The GeoBIM database main window is shown in Figure 2.



Karta	ID	Original-ID	Metod	X0	Y0	Z0
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	5	15ATAI03	Jord-bergson...	6539349,158	122517,116	25,283
	6	15ATAI04	Jord-bergson...	6539464,641	122604,099	22,401
	7	15ATAI05	Jord-bergson...	6539471,457	122610,705	21,892
	8	15ATAI06	Jord-bergson...	6539488,08	122624,174	21,52
	9	15ATAJ01	Jord-bergson...	6539016,811	122227,116	13,139
	10	15ATAJ03	Jord-bergson...	6538902,995	122115,328	5,354
	11	15ATAJ04	Jord-bergson...	6538840,885	122050,146	5,662
	12	15ATAK01	Jord-bergson...	6539108,054	121953,213	15,086
	13	15ATAK02	Jord-bergson...	6539015,777	121886,122	11,691
	14	15ATAK03	Jord-bergson...	6538915,492	121813,15	8,746
	15	15ATAK04	Jord-bergson...	6538795,063	121725,6	10,919
	16	15ATAL01	Jord-bergson...	6539039,824	121896,361	11,999
	17	15ATAL02	Jord-bergson...	6538961,378	121807,054	9,688
	18	15ATAL03	Jord-bergson...	6538909,093	121747,578	10,644
	19	15ATAL04	Jord-bergson...	6538847,039	121676,926	12,032
	20	15ATAL05	Jord-bergson...	6538792,727	121613,238	11,421

Figure 2 The GeoBIM database main interface with the columns; Map link, ID1, Original ID, Method, Coordinates - X, Y, Z, Value

2.2 Modelling

Following the infrastructure (or any) design process the first geotechnical job after having organized the geotechnical data is to start the geotechnical modelling, to find out the geometry of the soil volume and to characterize the different materials, fracture zones, groundwater chemistry etc. With a proper 3D modelling tool this could be done. On the market there are at least 200 different programs producing some kind of geological or geotechnical model. The GeoBIM concept does not promote any specific programs, but focus on making any of them directly useable from the GeoBiM database. In Figure 3 a 3D geologic model example is shown.

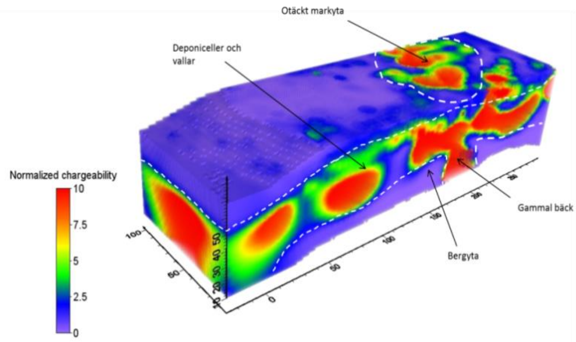

Figure 3 Geometric 3D model showing different properties in a soil volume. Example from Filborna landfill, Helsingborg, Sweden.

2.3 Design work

The geotechnical model defines the physical environment for any project in the building/infrastructure industry. Any building, road, tunnel, railway etc is founded on, or in, the ground, which could be soft soil, hard rock, a combination or anything in between. It is obvious that the most reasonable effort should be spent on finding out the most true geotechnical model. When the imaginary structure is put/placed in its planned environment, which means when you combine the structure design and the geotechnical model, the engineering design work starts. Typical questions raised are; Do we need to pile? Will there be a lot of water in the pit during the construction? Will the clay stand the weight of the building not to get too large settlements? A good geotechnical model and the ability to combine the model with the construction in the design tools (typically Civil 3D) will increase the chance for an optimized design. See Figure 4.

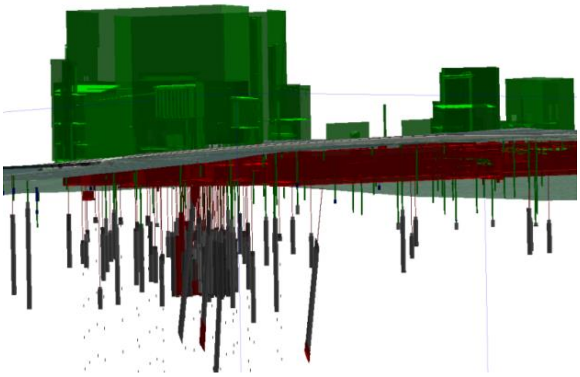

Figure 4 The order of success of the engineering design work is largely increased if the possibility of combining the geotechnical model, as well as the single geotechnical soundings, and the structure in the same design tool is good. Example from ESS, Lund, where the building is combined with the geotechnical model (top of clay till is highlighted) and parts of the sounding results. All information is handled as objects.

2.4 Visualization

Continuously through the design phase there is a need for visualizing geotechnical data and models. Not only for the geotechnical engineers responsible for interpreting the geotechnical data, but also for other engineering disciplines, clients, authorities, politicians etc. A good tool for visualizing the data and the model can't be overrated. See Figure 5.

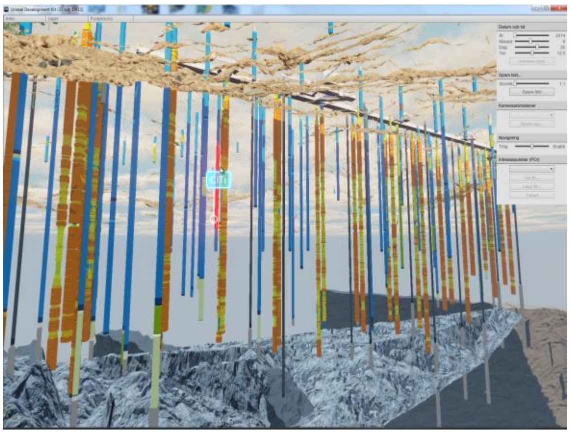

Figure 5 Visualization of geotechnical model and core drillings with the visualization tool TYREngine partly developed within the GeoBIM project. The tool is based on computer game technique, can be run by an X-BOX control unit and also in a VR helmet environment to get the full 3D potential/feeling. ESS, Lund.

2.5 Uncertainty model

The last part of the GeoBIM concept is the uncertainty model. This could be exemplified by the model of the rock overburden. In some areas it is often very well defined by observations of pure rock on the ground surface, whereas in other parts of the area the knowledge of the level is much less due to long distances between the boreholes. A graphical presentation of an uncertainty model is shown in Figure 6.

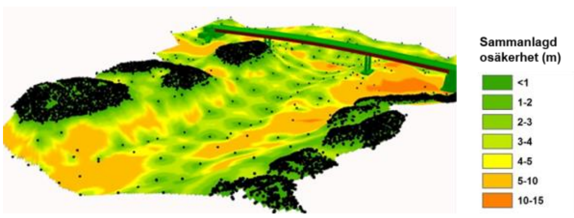

Figure 6 Uncertainty model. Example from Förbifart Stockholm (TRV, Golder)

3 POSSIBILITIES WITH GEOBIM

The GeoBIM concept will close the digital chain in the everyday geotechnical job, overbridge the remaining gaps such as rewriting soil classification between field, lab and geotechnical GIR reporting. The main contribution is however the generalization of the data format giving a number of new opportunities in the fields presented in chapter 2 above, and further explained below.

3.1 Data storage and archiving

With data stored in a general data format all geotechnical data can be stored and organized in the same database. Hence it opens up for better control of whole/complete data sets and long term archiving of data. A complete national geotechnical data archive?

In the projects where the GeoBIM concept have been pilot tested, i.e. Varberg railway tunnel, ESS, the speed with which a geotechnical model can be updated has been at least a magnitude quicker than using former technique, thanks to keeping all data in the same place and data format.

3.2 3D modelling

The possibilities with all data in a common database are many. All the available data can be used in the same 2D/3D modelling software (of your choice). It also opens up the possibility of using a number of modelling software that traditionally not have been used in the geotechnical industry. This will also give a better preciseness of the interpretations and a more precise final geotechnical model. It also gives opportunities for a quicker updating and communication of the models.

3.3 Design process

With the ability of using new geotechnical modelling tools the geotechnical models can be exported as objects to the design tools (ie Civil 3D, Microstation) in he preferred data formats. The other way around, many of these geotechnical modelling tools can also import the designed structure. The software that have been tested during the GeoBIM project have shown to almost seamlessly being capable of moving the models/objects between each other, making the design process (comparing how the current design of the structure fits the geotechnical model) much more convenient than today. An example is shown in Figure 7 (Varberg railway tunnel design). The models/objects that are exported can also keep information, meta data and features between the different software.

3.4 Visualization

Today different data sets are visualized in different format – from paper to 3D models – and it is obvious that the preciseness and full interpretation potential can not be reached. With the ability of visualizing all data sets in the software those parameters will be much improved. The potential of good visualization can hardly be overestimated. And the potential gets larger the less the audience knows about geotechnics. And the partners (more or less) interested in geotechnical data are many:

- Geotechnical engineer
- Other engineering disciplines (bridge, road, railway…)
- Client
- Contractor
- Environmental authorities
- Society/Community
  Stake holders

With a good and custom made visualization of the geotechnical data and the models all these partners can be reached. This has not been the case with 2D profiles on paper.

For non-geotechnical partners the visualization tools developed in the GeoBIM project have evolved to be a proper communication tool of the whole geotechnical work, clarifying a lot and largely impressing and widening the audience caring for what is underground.

One of the key factors for the success is that technique from the computer game industry have been used. With the two aims of handling really large sets of information and get a more realistic imaging of the underground the core/engine used in computer games is used for processing the geotechnical data sets. The models can also be controlled by an X-Box-unit. To get the final realistic feeling one can also put on a VR-helmet and get a full 3D experience, see Figure 5.

4 EXAMPLES

4.1 ESS – European Spallation Source, Lund

The ESS facility is designed in close cooperation by the partner group researchers-client-consultant-contract under a partnering contract. Since this means designing as you go it requires quick decisions, often redesign and a need for very competent geotechnical modelling and design tools. With using the whole GeoBIM concept those needs have been reached. In Figure 4 parts of the geotechnical model, and parts of the geotechnical soundings are visualized together with the current design of the facility. The design group use this tool on-line on meetings to test how different design aspects are affecting the geotechnical aspects.

4.2 Varberg railway tunnel

A common question in all rock tunnel design projects is: "-What is the rock coverage?" In this project this question was quickly answered in detail by combining the bedrock surface model and the current tunnel design (of that day) exported to the geotechnical modelling software where the calculation of the difference between the bedrock and the tunnel roof was calculated. The result was plotted as iso surfaces on the tunnel roof. This was carried out very quickly.

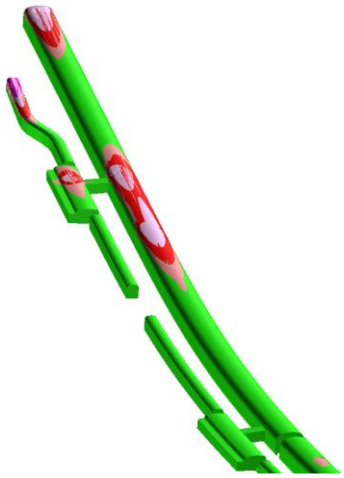

Figure 7 The rock coverage calculated and projected on the tunnel roof for the Varberg railway tunnel.

The bedrock model itself was to a large extent retrieved from seismic measurements, carried out by another TRUST project from Uppsala University, see Mahemir A., 2015. A large number of landstreamer seismic lines were carried out, see Figure 8. After processing and interpretation the seismograms are visualized together with the proposed tunnel line at an early stage, with the purpose of avoiding the most unfavourable rock fractures etc, before the more detailed design is started, see Figure 9.

Figure 8 Landstreamer seismic lines carried out within the Varberg railway tunnel project, primarily to identify the bedrock surface and the rock quality.

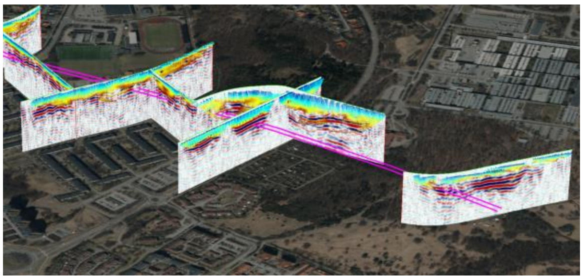

Figure 9 Processed seismic data visualized on top of the aerial photo and combined with the tunnel line in an early stage, to get a first idea of for example any large fracture zones are in an unfavourable position.

4.3 Ostlänken, high speed train – where the first full scale GeiBIM concept is introduced

The design of the next generation of railways in Sweden have started, the eastern part is called Ostlänken, and is split in four design sections. On the section OLP4 the GeoBIM concept will be tested in full scale, resulting in a geotechnical BIM delivery. The field investigations so far have basically included geological outcrop mapping and geophysical (GPR and Resistivity) profiling, and a few soil-rock soundings (Jb). Those three data sets are, in terms of data type, of very different character. With the GeoBIM database all data types are generalized and thereby it has been possible to combine them in a common modelling tool, see Figure 10, and hence produce a comprehensive bedrock model.

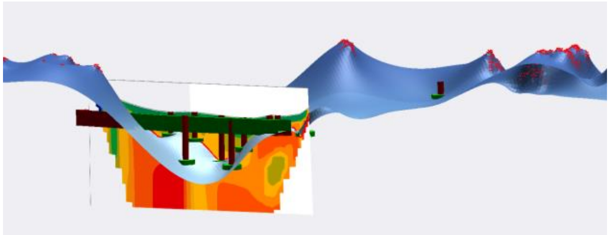

Figure 10 Bedrock model retrieved from three very different data sets – manual geological outcrop mapping, 2D resistivity profiles, soil-rock soundings (Jb) in the Ostlänken (OLP4) high speed train project.

5 UNCERTAINTY MODEL – RISK EVALUATION

Money rules. That is most often the reality. In large infrastructure projects this specifically counts for the unknown risks. The client often knows there is a number of risk, but the usual problem is to put a figure on the risks. Therefore the cost for the unknown risks often makes up a large part of the project budget. The GeoBIM concept has the potential of putting figures on the uncertainties. The potential is large thanks to the good order of the data that can be kept in the GeoBIM database. All data imported to the database can be accompanied with a figure of uncertainty, and further on used different levels of uncertainty estimations or calculations. An example of the concept is shown in Figure 6. The uncertainty module is the final part of the GeoBIM project, and will be the main focus during 2016.

With a well-established uncertainty model of the different geotechnical properties the client can handle the risks, and even use this during the contract process hiring contractors. The risk sharing will then be taken to a new level. Within the GeoBIM project also models for calculating the amount of necessary complementing investigations that are needed to lower the risk to a certain level are developed, Prästings et al, 2014.

6 GeoBIM DELIVERIES

Until today the final delivery of geotechnical data and models to TRV have consisted of:

- Field data as digital data files
- Factual report (GIR / MUR) (pdf)
- Geotechnical PM (pdf)
- Geotechnical 2D models (pdf, digital AutoCAD)

During 2014-2015 also geotechnical information have been required to be delivered as BIM models. However, the definition by TRV is most often vague. However, during the implementation of the GeoBIM concept a definition has evolved and the following definition of a geotechnical BIM delivery is proposed:

- Field data as digital data files
- The GeoBIM database (-format)
- Digital 3D model (object, incl meta data - properties)
- Digital uncertainty model

The GeoBIM welcomes a discussion on this definition.

7 TRUST

The GeoBIM project is run under the TRUST umbrella, which is a cooperation of nine sub projects, separated in three different types of projects; a) development of preinvestigation methods, b) developing methods and techniques concerning the construction phase, c) development of tools for information handling and visualizing of data and models, see Figure 11. The total budget is 75 million SEK, 2013-2017. Six universities are participating; Lund University, Chalmers, KTH, LTU, Uppsala University and Arhus University. 10 PhD students and approximately 30 senior researchers. Tyréns and NCC are the industry partners. See also www.trust-geoinfra.se and Ask M., 2014; Svensson M., 2015; Hagberg P., 2015; Johansson S. et al, 2015; Malehmir A., 2015; Sparrenbom C., 2015).

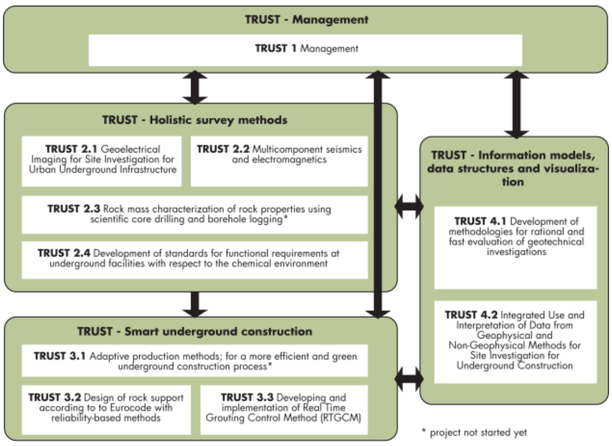

Figure 11 TRUST projects (www.trust-geoinfra.se).

8 SUMMARY

The core of the concept is the GeoBIM database storing data in a more general data format than before – opening up a large number of geotechnical related possibilities. The most important may be a tool for sharing the costs for geotechnical risks in a project and a new way of communicating geotechnical data and models, reaching a much larger community than before.

9 ACKNOWLEDGEMENT

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