DIGITAL GEOTECHNICAL INFORMATION MANAGEMENT FOR LIFECYCLE RESOURCE SAVINGS

M. Svensson[1], O. Friberg[2]

KEYWORDS

Uncertainties, geomodelling, digital twins, multivariate analysis, GeoBIM

ABSTRACT

A digital geotechnical data management platform capable of handling all geotechnical information produced through the whole life cycle has been developed. By combining information from desk studies, geophysics and geotechnical sounding and sampling information in the same platform, geomodels of the subsurface conditions can continuously be refined from planning to construction. Finally, an as built 3D model of the subsurface built environment including geology, geotechnical design properties and permanent geotechnical structures can be handed over for asset management to the client for future maintenance use.

Microsoft 365 Teams was chosen as a general platform for implementing the GeoBIM concept for managing all geotechnically related data, including geophysics and geotechnical structures. The tool implements outcomes from recently developments on uncertainty handling in geological layer modelling and soil mechanical design values.

When all data are gathered in the same environment it also enables implementation of advanced interpretation functions. Specifically valuable is the uncertainty module for defining layer models with corresponding uncertainties and objectively determining soil mechanical design values using MVA methodology. Therefore, an updated and much improved geotechnical design process governed by well-defined uncertainties is suggested.

When all geotechnically related subsurface information – data, models, geotechnical structures – are easily available, visualized and communicated in a common platform, and advanced tools for QA and analysis of both data and models are in place, a geotechnical digital twin of the subsurface can be defined.

[1] Tyréns AB, Helsingborg, Sweden, mats.svensson@tyrens.se
[2] Tyréns AB, Malmö, Sweden, olof.friberg@tyrens.se

Since the database is also prepared for handling sensor data in time series this opens for scenario modelling of future possible geotechnical events. For example, by continuously collecting settlement data or pore pressure data and frequently applying those on stability analyses in sensitive sections defined in the geotechnical digital twin, a proactiveness for preventing for instance landslides will be achieved.

1. BACKGROUND

When a road, bridge or railway is to be built it is crucial to know the geotechnical conditions, including hydrogeology and the environmental situation. All information about the subsurface conditions is most often collected using geotechnical drill rigs and is done to a different extent depending on current project type and project phase. At an early stage only archive material is used, whereas at a later stage more detailed investigations are carried out. Every investigation gains valuable information which nowadays most often is digitally collected. Heading towards sustainability and hence a lifetime perspective, today we also need to take the geotechnical asset management phase into account.

Although different initiatives on handling smooth transferring and standardization of geotechnical data formats have been ongoing since many years (AGS, LAS, SGF, buildingSmart, OGC, DIGGS, IFC, CoClass) there is still a long way to go until full compatibility between all data and all software in the geotechnically related subsurface disciplines will come true. Therefore, still planning of geotechnical investigations are often non-optimized and the full potential of the whole geotechnical data set is seldom used. Sometimes data sets are even lost between different phases and different stakeholders.

With the vision of full transparency between all project phases and all stakeholders from idea to demolition of a structure the GeoBIM concept has been developed, see figure 1, enabling:

- Easy access to all data (geotechnical, environmental, geology/rock, groundwater, geophysics) for all stakeholders always
- Design managed by known geotechnical uncertainties
- Flexible workflow and quick adaption to the user needs and specific software

This not only allows a smooth, quality assured and efficient workflow for any geotechnical design applications, it also enables a significantly updated geotechnical process.

Having all data in good order in a professional and well-structured database is fundamental for applying a digital workflow. It is also crucial for making use of the new universe that has opened with IoT and AI methodologies.

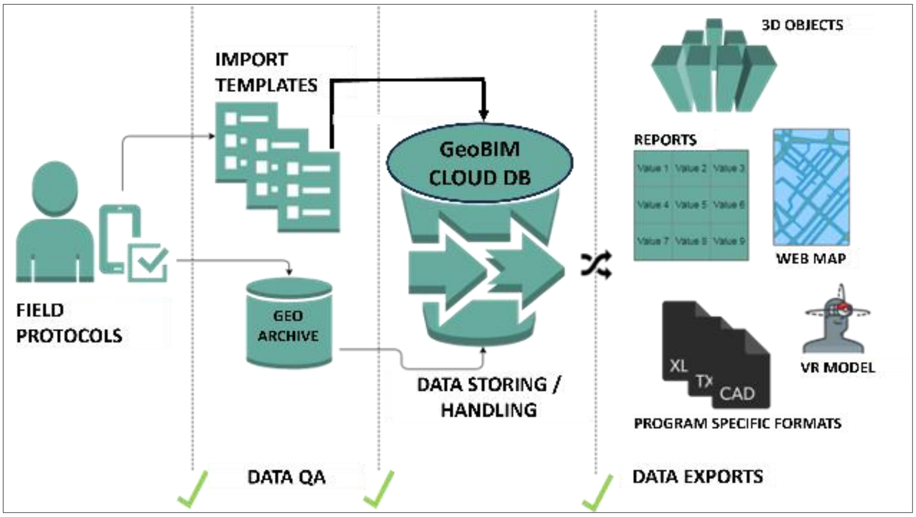

Figure 1 The GeoBIM concept process, enabling a completely closed digital chain from field data collection to 3D geo-model or other deliverables. [1]

2. INFORMATION LOSS

Still, and often, unforeseen geological and geotechnical conditions are pointed out for causing delays and more costly infrastructure projects. A limited openness between different stakeholders being reluctant sharing knowledge and data is one of the reasons, often governed by contract issues.

In the procurement phase (design and build contract) the client often only supplies the contractor with the geotechnical factual report, although a lot of job has been spent on interpreting the geotechnical conditions producing geomodels during the design phase. This often results in differing interpretation of the geotechnical conditions, long discussions and possibly a claim situation.

In the end of a project the asset owner, often the client, most often miss systems and routines for storing and manage all information about the subsurface conditions, for example where piles in detail have been installed. Keeping in mind in Sweden infrastructure assets are designed for a lifetime of 120 years, detailed geotechnical as built information, including geotechnical structures, could be very valuable when a bridge is to be widened etc. during it´s whole lifetime.

If there was a transparency between different stakeholders and the different project stages data would continuously be shared with the other actors, see figure 2, and many issues would be prevented and less claims would be the case. The GeoBIM concept suggests and facilitates such a process, see chapter 5.

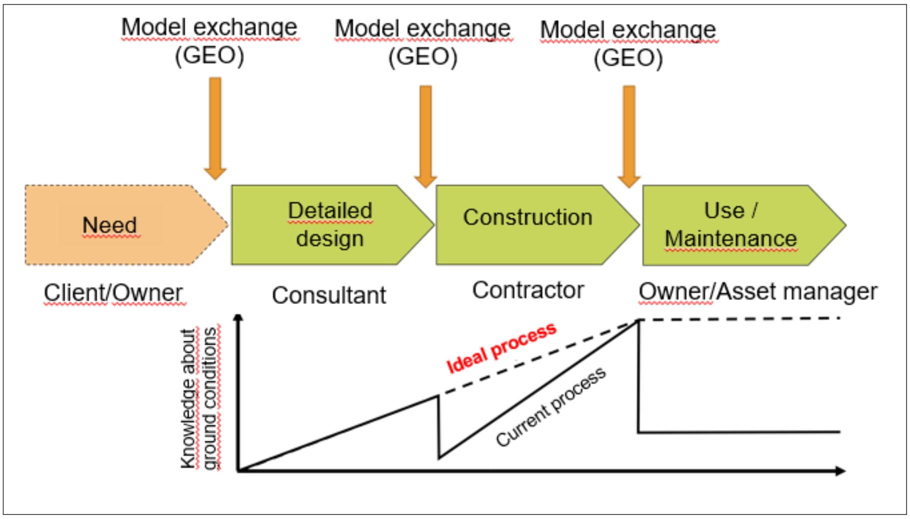

Figure 2 When handling geotechnically related information between each phase and each stakeholder in projects there is an information loss. Often there is also a significant information loss between different disciplines within the same company or project team. The figure also illustrates the preferred process, in red.

3. GEOTECHNICAL DATA MANAGEMENT PLATFORM

The GeoBIM data management platform and concept emanate from three principally different uses within the geotechnical process:

- Data handling and storing
- Daily geotechnical craftsmanship
- Advanced data analysis

Data handling and storing

The database is prepared for importing/exporting all geotechnically related data types used in Sweden (2024). When standards are available, for example the SGF data format [4], this is used. For other methods experts in each field (environmental, geophysics etc.) have defined a preferrable data format. After a validation process for quality assurance data is uploaded in the database, which holds approximately 250 000 boreholes (2024). All boreholes are visualized in a map view.

Daily geotechnical craftsmanship

The daily geotechnical design work starts with producing a factual report (GIR) including sounding and sampling data from field investigations. Having all data well organized much of this work could be automated and quality assured. An example is comparing all borehole ground levels with the digital elevation model (DEM). When there is a misfit, the user will be notified to eliminate such fundamental misinterpretations. Transforming all sounding data to shear strength diagrams using all empirical relations is another efficient and quality assured basic tool, enabled by the fully digital workflow.

Advanced data analysis

The efficiency of having access to all data in a project in the same digital environment makes it possible to implement use of advanced interpretation tools that have been developed in previous separate R&D projects, run by experts. In those cases, the specific data sets which are to be used are automatically gathered in the preferred way tailor made for the specific application. Most interesting are tools for handling geotechnical uncertainties and statistical analyses of contaminated volumes, see chapter 4.

Microsoft Teams application

Two key factors while developing the digital concept have, firstly, been to be avoid developing tools and features which are already available in the industry (most often under expensive licenses) and, secondly, give easy access to the digital tools for any stakeholder.

Therefore, all GeoBIM functionality has been implemented in the general Microsoft 365 Teams platform, including for instance tools for determining uncertainties on layer geometries using Monte Carlo simulation technique and design values using MVA methodology, see chapter 4. Each tool is run upon request, see figure 3, and the geometry uncertainty models and the MVA results are stored in the digital platform.

Microsoft Team is used by most of the stakeholders in the industry and hence access to all functionality could easily be given to all parts in projects, including for example environmental authorities, without expensive licensing.

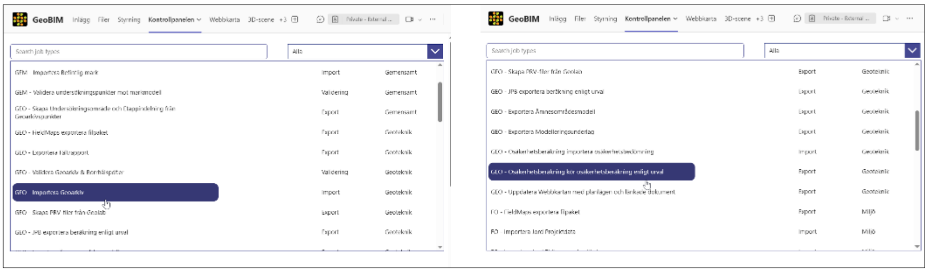

Figure 3 The Control panel interface of the GeoBIM platform. Left: Import field data Right: Run bedrock overburden incl uncertainty algorithm.

Geotechnical structures

To reach the definition *a complete geotechnical asset management model* it is also necessary to incorporate the geotechnical structures that are installed during the construction. Since there are no standards for this also here experts from the industry in Sweden have agreed on which information is valuable/necessary to maintain in the database for asset management purposes, see figure 4. The agreed necessary information has been formalized in delivery specifications which are available for download from the GeoBIM platform. Specifications for piles, pile decks, anchors, sheet piles and LC columns are available (2024).

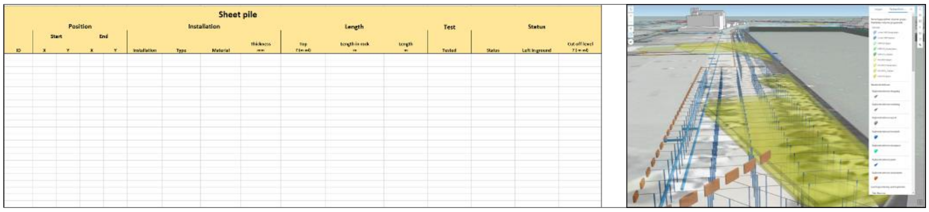

Figure 4 Left: Standardized data format – delivery specification **-** *for importing geotechnical structures (sheet piles) to the GeoBIM database. Right: Visualization of geotechnical structures stored in the GeoBIM database (Project Nyhamnen, Malmö)* [5]

4. UNCERTAINTY CONTROL

A big issue in geotechnical engineering is the large proportion of uncertainties concerning both the geological model and the design values. There are a few reasons for this – the natural geological variation, transformation errors when converting from sounding results to engineering properties etc. The results are presented in factual/baseline reports and design reports (GBR, GDR). However, there is no standardized procedure for specifying the uncertainties, neither concerning the stratigraphy or the design values, i.e., undrained shear strength.

Within the GeoBIM concept tools have been developed for handling both the uncertainties of the layering, i.e., the bedrock model, [2], and the design values, [3]. For determining the uncertainties of the bedrock overburden an algorithm based on individual uncertainties assigned to each sounding have been developed. Also, the distance to the nearest sounding point is used in the algorithm. After a Monte Carlo simulation (1 000 models) the outcome are three bedrock overburden models and an uncertainty map, see figure 5.

The algorithm that has been developed is validated to five uncovered and surveyed bedrocks in infrastructure projects in Sweden. The prediction accuracy was shown to be 0.4-0.9 m [2].

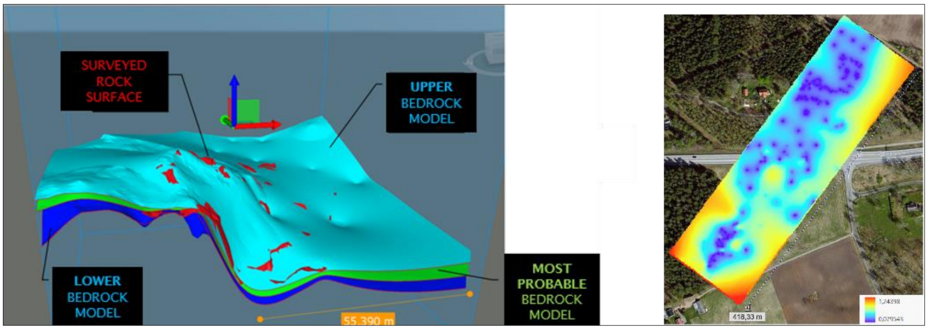

Figure 5 Results from modelling the top of the bedrock. Left: most probable bedrock model, upper and lower bedrock models within 95% probability. Right: Uncertainty map, plan view of most probable bedrock model. [2]

To get an objective prediction of the undrained shear strength a tool using Multivariat analysis (MVA) has been developed. The methodology for geotechnical applications is well validated in [3]. The GeoBIM platform has implemented a module grabbing data of the user's choice in the database and performing an analysis using the MVA methodology. The result is presented with an objectively determined undrained shear strength accompanied by a known uncertainty (COV), see figure 6.

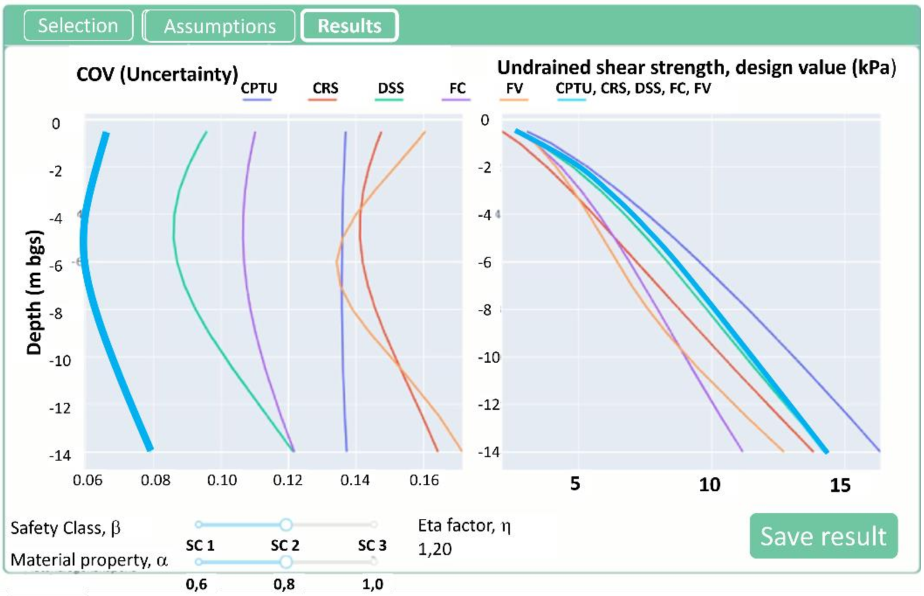

Figure 6 The undrained shear strength determined using MVA methodology. The combined uncertainty is significantly lower than the individual uncertainties from each method. Figure modified from [2].

5. UPDATED GEOTECHNICAL PROCESS

Keeping all geotechnical data well-structured and in good order in a professional database shows that the daily geotechnical design work could be fully digitalized, and advanced and novel applications more commonly utilized, such as uncertainty models of geometries and MVA methodology for objective determination of design values.

Irrespective of phase in a project this opens for defining a new geotechnical process and workflow, based on *known uncertainties*, see figure 7. A new geotechnical workflow is suggested, governed by a constant update of the uncertainties both concerning the geologic model and the design values. As soon as any new information is added to the database the uncertainties are recalculated and compared to the allowed uncertainty criteria decided at the beginning of the project or current phase. Following this process activities like investigation programs could be optimized, risk sharing between client and contractor could be clearer and the GBR/GDR could also become more defined.

With the vision of this suggested workflow, not taking legal aspects into account, all stakeholders constantly have access to the same updated information via the same digital platform/database where both data and models can be visualized.

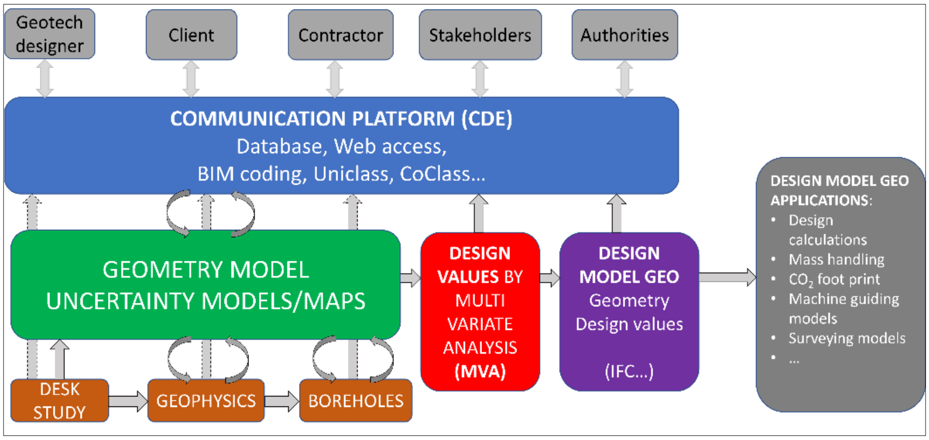

Figure 7 A new geotechnical process is suggested, based on known uncertainties, possible to define within the GeoBIM concept. Figure modified from [2].

6. SENSOR DATA AND DIGITAL GEOTECHNICAL TWIN

Having reached the level of fully digitalizing the geotechnical process from field planning to handover of a geotechnical asset management database and model for the client to use in an asset lifetime perspective one could dig deeper into the digital field. Inspired by the IoT sector recently the GeoBIM team therefore has started to implement structured handling and management of streaming sensor data, starting with automatic meters for groundwater levels, see figure 8, and tunnel movements monitored by extensometers, see figure 9. An obvious use of streaming sensor data, certainly during the construction phase, is to continuously compare the movements/levels to set alarm levels.

A more sophisticated and state of the art use is combining the data in the database, the interpreted geomodel from the design phase continuously updated with true values during construction (typically surveyed bedrock surface) and the streaming sensor data, using AI methodology for training an AI algorithm for predicting future geotechnical behavior.

In this process also the design FE models could be calibrated and used for predicting future geotechnical scenarios. The digital geomodel, including not only geometry and physical properties but also a geotechnical behavior, could then be considered *a digital geotechnical twin.*

Even in projects where everything goes according to plan, the continuous follow-up of the geotechnical behavior is highly valuable as it gives the project members a security that everything is under control.

By combining information from previous stage investigations and predictions with continuously inflowing sensor data in the same system, reasons for deviations between expected and actual results could also quickly and rationally be identified, enabling the right decisions to be taken in time.

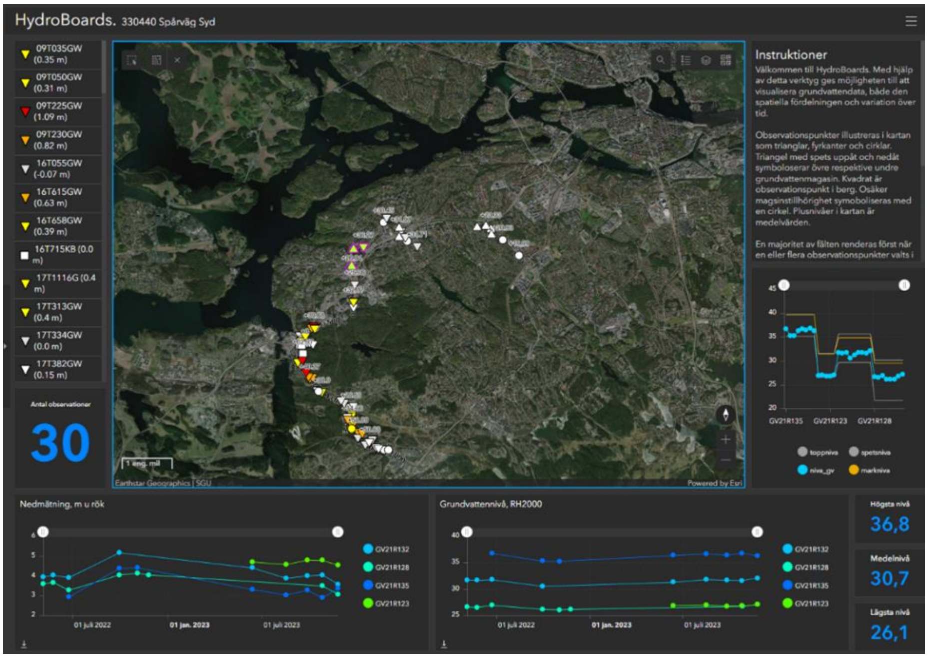

Figure 8 Hydrogeological time dependent sensor data visualized in the Microsoft GeoBIM in Teams platform, currently semiautomatically updated, but soon to be continuously streaming into the database. Project Spårväg Syd, Stockholm.

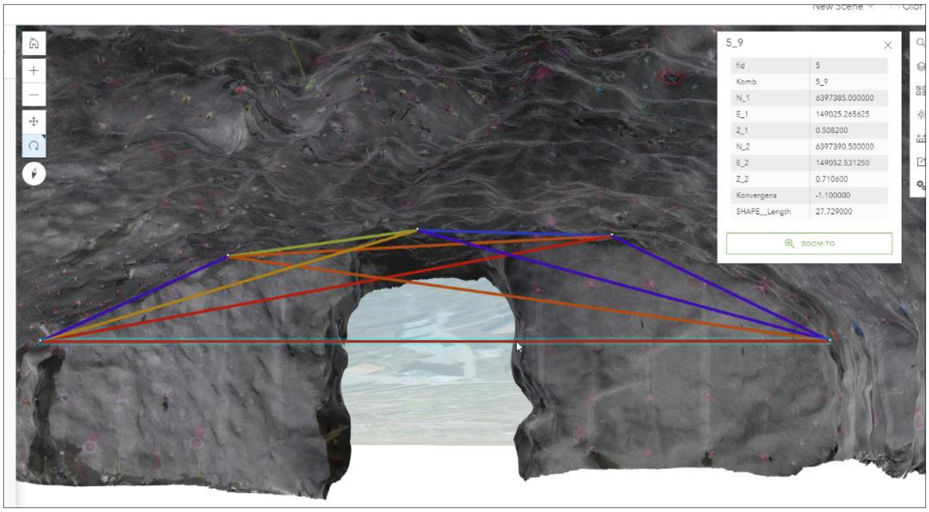

Figure 9 On-line monitoring of extensometers in a tunnelling project in Sweden. All data is monitored and stored in the database and continuously compared to set alarm levels.

7. CONCLUSIONS

A digital geotechnical information management platform for a lifetime perspective has been developed, based on the GeoBIM concept, and implemented in the Microsoft 365 Teams shell for increased accessibility in the industry.

The database and the accompanying methodology enable quality assurance, easy access to data, models, and geotechnical structures for all stakeholders through all phases. Using the GeoBIM concept will decrease geotechnically related risks, miscommunication, and the number of claims. It also allows flexible and advanced analyses using the whole data set.

This opens for a new updated geotechnical process governed by uncertainty control of geotechnical parameters. At the end of a project a complete geotechnical model could be handed over to the client for maintenance use.

Implementing a new geotechnical design process as suggested requires overcoming legal issues and since long well-established workflows. Good use cases, education of the geotechnical community, including the environmental, geophysics, rock, and groundwater disciplines, and openminded early adopters among all stakeholders are key elements for succeeding.

In the era of IoT, monitoring of geotechnically related streaming sensor data is implemented in the geotechnical data management GeoBIM concept enabling geotechnical digital twins to be defined. This opens for geotechnical scenario studies in any project and also proactiveness for preventing natural hazards.

However, abovementioned requires commonly agreements on standardized data formats and processes and more transparency and trustfulness between all geotechnical stakeholders. No matter how sophisticated tools and processes that are developed by single players if the geotechnical community as a whole don´t collaborate. The technology for giant geotechnical leaps is here. Are we, as a common geotechnical community ready?

ACKNOWLEDGEMENT

The digital geotechnical information management platform, the GeoBIM concept, has been developed with financial support from Sven Tyréns Foundation, Smart Built Environment, Swedish Rock Engineering Research Foundation (BeFo), The Development Fund of the Swedish Construction Industry (SBUF) and The Swedish Road Administration (TRV).

REFERENCES

[1] M. Svensson M. and O. Friberg, Effektiv kommunikation av georelaterad undermarksinformation i ett LCC-perspektiv, Grundläggningsdagen 2019, Proceedings, Mars, 2019

[2] M. Svensson and O. Friberg, GeoBIM for handling geological and geotechnical uncertainties in tunnelling, ITA-AITES World Tunnel Congress, WTC2022, Bella Center, Copenhagen 22-28, 2022

[3] A. Prästings, Managing uncertainties in geotechnical parameters: From the perspective of Eurocode 7, PhD thesis, KTH Royal Institute of Technology, 2019

[4] SGF, SGF:s dataformat, SGF Rapport 3:2012 (in Swedish), Swedish Geotechnical Society, Linköping, 2012

[5] M. Svensson, O. Friberg and D. Hagerberg, GeoBIM for increased efficiency of the remediation process of contaminated sites, Smart Built Environment Report nr U8-2020-06, (in Swedish), 2023