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Full underground BIM via development of CoClass for geotechnical data, models and objects

BIM souterrain complet par le développement de CoClass pour les données géotechniques, les modèles et les objets

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ABSTRACT: The whole of society is rapidly heading towards digitization. LCC (life cycle cost) is soon to become the governing driver for the design process in the building industry, and with that follows asset management and maintenance of all facilities. This gives new aspects to geotechnically related data, models, structures and objects, which has previously not been considered within the geotechnical community. Four key factors have been identified as crucial for handling geotechnical issues in this new arena, all the way from planning of field work, through interpretation, 3D modelling and reporting, to asset management: 1) Well organized data, 2) Standardization of data structures, 3) Classification of objects, and 4) Standardized data exchange formats. In the GeoBIM concept (www.geobim.se, www.trust-geoinfra.se) the first two issues were dealt with and GeoBIM is well accepted for the second level of geotechnical BIM by the Swedish Transport Administration (TRV). In the R&D project "Further development of BIM through the standardization of underground information to enable innovative new processes and applications in the building industry" the two remaining issues are studied and developed. In this paper the whole GeoBIM concept including the CoClass system for the underground space is presented.

RÉSUMÉ Toute la société se dirige rapidement vers la numérisation. Le CCV (coût du cycle de vie) deviendra bientôt le moteur du processus de conception dans le secteur du bâtiment et, par conséquent, la gestion des actifs et l'entretien de toutes les installations. Cela crée des nouveaux aspects des données, modèles, structures et objets géotechniques au sein de la communauté géotechnique. Quatre facteurs clés ont été identifiés pour gérer les problèmes géotechniques sur ce nouvel espace, à partir de la planification du travail sur le terrain, par l'interprétation, la modélisation 3D et le rapport, à la gestion des ressources: 1) Données bien organisées, 2) Normalisation des structures des données, 3) Classification des objets et 4) Formats standardisés d'échange de données. Dans le concept GeoBIM (www.geobim.se, www.trust-geoinfra.se), les deux premières questions ont été traitées et sont bien acceptées pour le deuxième niveau de BIM géotechnique par l'Administration suédoise des transports (TRV). Dans le projet de R & D «Développement du BIM par la standardisation des informations souterraines pour permettre de nouveaux processus et applications innovantes dans l'industrie du bâtiment», les deux questions restantes sont étudiées et développées. Dans cet article, l'ensemble du concept GeoBIM est présenté.

Keywords: GeoBIM, CoClass, underground space, 3D model, geotechnical

1 INTRODUCTION

The underground space is increasingly used for a wide range of purposes, with urbanization being one of the main driving forces (Lindblom et al., 2018). Continuously increased urbanization rates inevitably impose the need for underground infrastructures and hence an improved city planning mindset, including both the surface and the underground space (Broere, 2015; Liu and Chan, 2007). A fundamental need regardless the design of the various facilities is that they all need to handle the geological, hydrogeological and geotechnical conditions below the ground surface. The processes for realization of those facilities also engage many disciplines and organizations – engineers, designers, architects, clients, contractors, stakeholders, authorities. All these different parties need to communicate, amongst others, on the underground data and the interpreted underground space conditions, in an LCC perspective. In many aspects this is not always an obvious and quality assured process. Some of the reasons for this are, for example:

- lack of standardized data structures and their inconsistency for geotechnically related data, making efficient quality assured joint interpretation complicated and cumbersome,

- advanced software for interpretation of geotechnical data and modelling, resulting in long processing time and high costs,

- expensive licenses for visualizing data and models, resulting in low accessibility to data and models for many stakeholders,

- lack of transfer formats for data and models between different disciplines and stages along the process, making the workflow inefficient and quality assurance sometimes low.

Since the society across the globe is heading towards digitalization (e.g., the concept of “smart cities”) there is a lot to gain if different data structures and transfer formats for geotechnically related data and objects could be standardized.

This paper’s aim is to clarify the need for better communication tools in the tunneling, geotechnical and the infrastructure design discipline and to suggest several solutions and ways forward on the aforementioned issues. A few examples where the GeoBIM concept has facilitated and provided better environment for which this communication has successfully been done are presented. The recently developed CoClass codes for underground geotechnical objects is suggested as the language to use for standardizing the communication, also in an LCC perspective.

2 GEOTECHNICAL MODELLING HINDERS AND REQUIREMENTS

The everyday mission for the geologist and the geotechnical engineer is to find out and in the best possible way define and describe what the underground space looks like, i.e. mechanical properties and geometry, sometimes called geotechnical modelling. In this work, a lot of data is handled, and several different software are used. It is not uncommon that the number of methods used exceeds one hundred. One of the biggest challenges is to make use of all the data available during the interpretation and the modelling stages. In Scandinavia, since the early 1990’s, there is a standardized data structure (SGF, 2012) used for geotechnical sampling and sounding data. The usage of this data structure makes it straightforward and convenient to handle and jointly interpret these data types, regardless which drill rig or data collection unit that is used. However, with most of the other methods used – core logging, groundwater, geological mapping etc., data and models are far from standardized, and bringing different data types together is a challenging and often time-consuming task. Therefore, it is common that the full potential of the combined data set is not reached, or simply formulated: there is a communication issue.

With the BIM requirements in infrastructure design, including also underground data and models, the industry driven initiatives showing the potential of communicating data and interpretations in 3D models together with designed facilities are being brought to spotlight. The GeoBIM concept is one of the concepts capable of integration, joint interpretation and visualization of all aforementioned. In project meetings, application of this concept has clearly shown to help clients and other stakeholders to understand the great potential for reaching a proper 3D geo-model. An example of integration of all data types in GeoBIM with different geo-data and models is shown in Figure 1.

2.1 Existing data formats

The most widely spread standard for geotechnically and rock investigation related data are the AGS format for geotechnical and geoenvironmental data (www.ags.org.uk) and the LAS data format for geophysical borehole logging data (CWLS). In Scandinavia and the Baltic countries, the data structure for geotechnical sounding and sampling defined by the Swedish Geotechnical Society is widely used (SGF, 2012).

Once the data structure hinders mentioned above are overcome, a more efficiently closed digital process would be reached. With this, the possibilities for better joint interpretation and generation of the most probable geo-model, including both geometry and properties of the underground space in 3D, would drastically increase.

3 UNDERGROUND DATA IN AN LCC PERSPECTIVE

Geotechnically related data are produced at many stages in a project along its road to the archive for long time management (typically over 100 years or through the expected life of the infrastructure). The different stages can be separated as:

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

3.1 Infrastructure design phase

The final aim of investigating and interpreting the underground space is to deliver a geo-model to the design team for the actual facility. This is a continuous process commonly requiring daily updates of geotechnical conditions available for design of foundations, handling of settlements etc. Those design disciplines most often use design software of a CAD-type. For an efficient workflow, this requires that the geotechnical modelling tools can communicate with the design software. For quality assurance purposes, it is quite beneficial if all sounding, monitoring and sampling data can be visualized in 3D in the same software, see Figure 1. Generation of this type of models requires data formats capable of communicating with each other, which is nowadays not always the case.

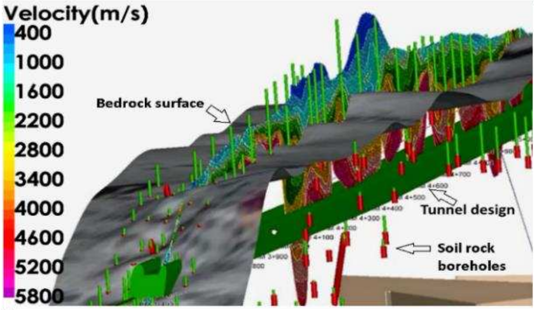


Figure 1. Various types of geo-related data and models are combined for joint visualization together with the current tunnel design in CAD design tools.

3.2 Visualizing data and 3D models

Traditionally, geotechnical and rock mechanical engineers, geologists and hydrogeologists are those working with the geotechnically related data, reporting the final models in 2D drawings or 3D models and/or in written reports for further use in the design process. These models seldom reach the full potential. By using modern 3D visualization tools, better quality assurance of all data is reached, and a larger group of stakeholders/parties can be engaged or involved during different stages of a project. Most important, the geo-model can be communicated in a pedagogic way and better and more optimized understanding and design can be gained, see Figure 2. In large scale projects, communication is the key factor for success, and the GeoBIM concept has proved to be successful in communicating all geo-related data and models in infrastructure planning projects (Svensson M. and Friberg O., 2018; Malehmir A. et al, 2015; Malehmir A. et al , 2018).

3.3 Data management

Data and models from infrastructure projects are managed differently in different projects and different countries, due to various reasons. If standardized data structures, data transfer formats and a data classification system was in place the prerequisites for national or project databases would be much better.

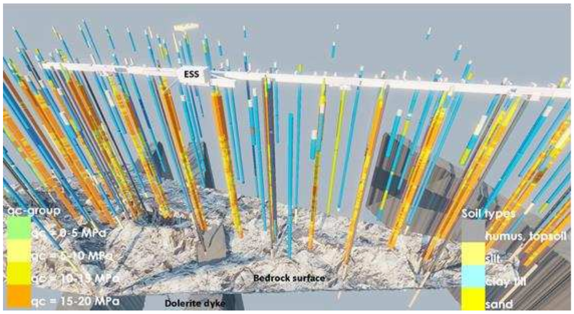


Figure 2. A geotechnical 3D model, core drilling data and current facility design visualized using computer game technique. A powerful tool for communication with non-geo public. Example from the European Spallation Source (ESS), Lund (Svensson M., 2015).

4 THE GEOBIM CONCEPT

The core of the GeoBIM concept is a database capable of handling - importing, storing, exporting – all geotechnically related data that are used in an infrastructure project, hence including data from geophysics, geotechnical sounding and sampling, rock cores, borehole geophysics, laboratory tests, groundwater and contaminated soil investigations. Figure 3 shows a block diagram of the GeoBIM concept. The GeoBIM concept relies on the database configuration and information accessibility.

4.1 The database configuration

Essentially, the database stores 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 an unlimited number of dimensions (what has been measured i.e. resistivity, velocity, time etc). This approach ensures that information from new methods may easily be added, and large amounts of data can be handled rationally since data are handled as a point cloud. The database model is implemented in a PostgreSQL database located in the Cloud.

4.2 Database access

To access the information, a database viewer and a web map has been connected, which are accessible through a GeoBIM Web portal (www.geobim.se) 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. CPT soundings, seismic profiles, borehole information, etc.). From 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 software they will be using. As an example, a project member responsible for the geotechnical modelling might be interested in all geo-data that can improve the interpretation of a rock surface model (e.g., Figure 1), while a geo-chemical engineer might want data to analyze a pollution propagation. The output from both these tasks is then used combined with raw field data in a BIM model, to review and share the results, see Figure 1.

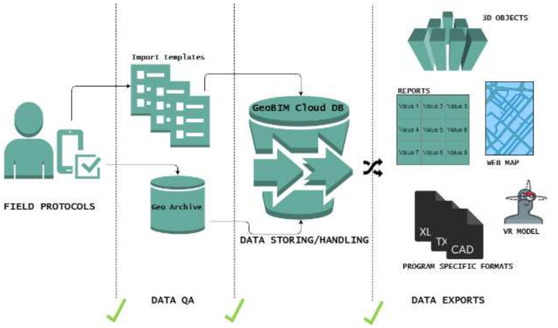


Figure 3. The GeoBIM concept process, enabling a completely closed digital chain from field data collection to 3D geo-model.

When geo-models are produced by skilled staff and according to design standards (e.g. Eurocode, 1997), making use of all available data and reviewed by cross discipline experts ensuring their interrelationships seem correct, the best possible interpretation can be performed. These models may thereafter be used for more accurate design and, for example, optimize mass balance calculations or reinforcement design, among others.

5 COCLASS FOR FULL GEO-TECHNICAL BIM

The next generation of the infrastructure design process focuses on full BIM and LCC (Life Cycle Costs) as the governing decision tool. This means that the maintenance phase is gaining a lot more interest than before, resulting in a need for systems where the facility and the accompanying data and information need to be accessible for 120 years or so (TRV design criteria). This is part of the global digitalization and there is a great opportunity and potential for a quicker and more precise process for producing 3D models of the underground space and aid in the infrastructure planning process at all stages. However, if this is to become reality, more standardized data structures, exchange formats and a standardized code system for underground objects need to be developed and widely accepted.

In an ongoing project the CoClass system is under development for underground objects, aiming at giving all geo-related underground objects a certain code, which will give all systems in the infrastructure process a possibility to identify that certain object (Table 1).

Table 1. Example of preliminary suggested CoClass classification system for underground objects.

Example of object	**Graphical representation**	**Example of code (preliminary)**
Sand sample	Point	A.AB01.ZGA.10
Seismic line	Line	A.AB01.ZGB.03
Surveyed outcrop	Area	A.AB01.ZGC.01
Contamination plume	Volume	A.AB01.UUF30
Clay layer (top level)	Surface (modelled)	A.AB01.UUB20

When CoClass is implemented for underground objects, any models can seamlessly start to be used by all parties in the whole design and building process. A contractor on site could, for example, easily find a bedrock surface model in the project database, bring it up on the screen and compare it with on line drilling results from a tunnel, in real time, regardless of what software is used, see Figure 4.

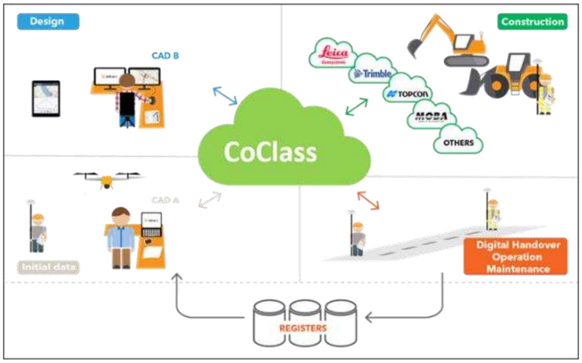


Figure 4 The princial of CoClass for seamless commuinication in an LCC perspective.

5.1 CoClass general hierarchy

The CoClass system (coclass.byggtjanst.se) is a Swedish initiative built on the international standard ISO 12006-2. The system (version 1.0) is already set for structures above ground and is now introduced and supported by the Building Smart organization (www.buildingsmart.org). CoClass is a hierarchical system starting at the level Objects, followed by Construction element, under which there are: Functional systems, Constructive systems and Components, see Figure 5.

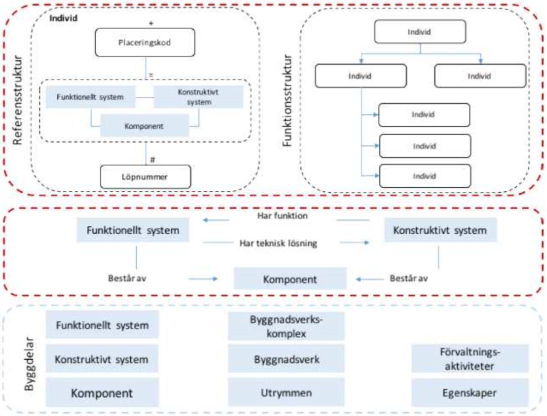
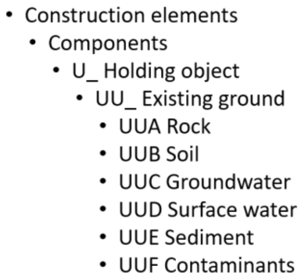


Figure 5 CoClass hierarchy in general. (www.svenskbyggtjanst.se)

5.2 CoClass geotechnical hierarchy

The ongoing project suggests a clear division between survey objects and modelled objects. Objects that represent results from field investigations are classified according to their results and method. The modelled underground geological objects are classified as Rock (incl fractures), Soil, Groundwater and Contaminants, see Figure 6. For further details types can be used, see Figure 7. For taking care of properties, such as shear strength, level of copper, groundwater level, within each type those can be defined as properties which are defined in accompanying lists of properties or as a reference to established national or international industry standards (for example SGF, AGS, Eurocode).



- Construction elements
  - Components
    - U_ Holding object
      - UU_ Existing ground
        - UUA Rock
        - UUB Soil
        - UUC Groundwater
        - UUD Surface water
        - UUE Sediment
        - UUF Contaminants

Figure 6 Suggested CoClass classification system for geo-related underground objects.

- *UUB Soil*
    - *UUB10 Friction soil*
    - *UUB20 Cohesive soil*
    - *UUB30 Mixed soil*
    - *UUB40 Organic soil*

Figure 7 Suggested CoClass structure for sub level Soil.

5.3 CoClass pilot test

During the initial pilot test, the focus has been on examining the exchange of information between the design phase and the construction phase. The test has shown that the proposed CoClass classification facilitates the information transfer. By applying CoClass, the recipients can quickly use the information in their respective activities.

The pilot test has also shown that further development of the properties list will be required to improve version management and description of uncertainties relating to the modeled objects. In Figure 8 a model based on CoClass-classified objects from the contractors detailed design tool is shown. All objects were classified by the consultant in the previous design phase and the model was transferred to the contractor for production of more detailed models for the different construction phases.

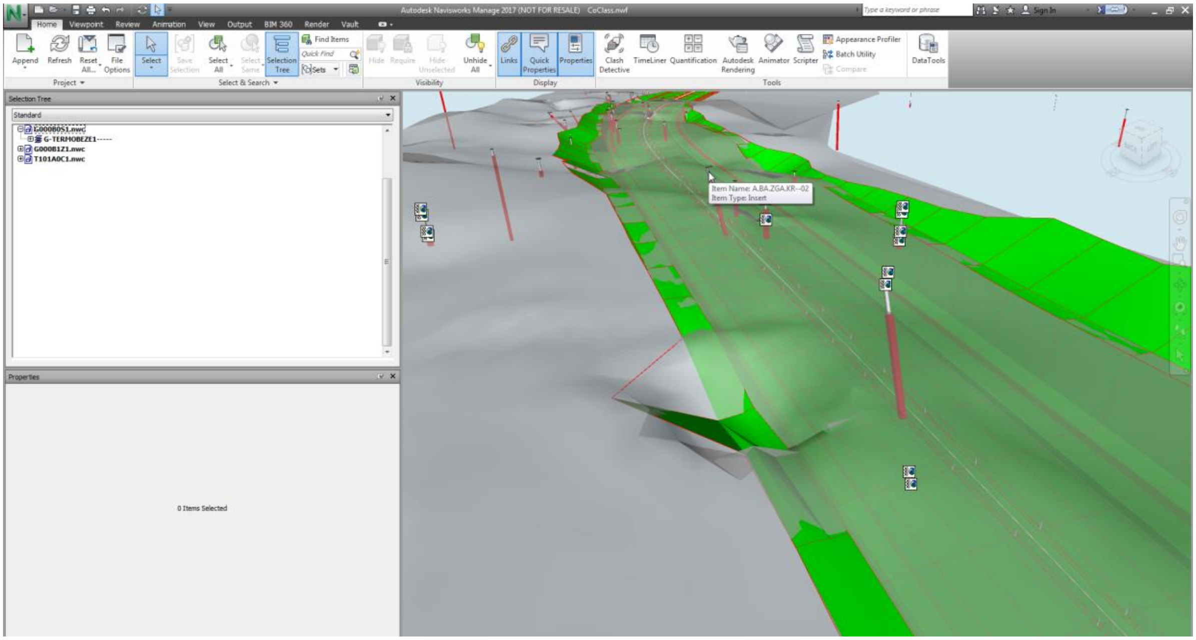


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Figure 8 Joint review model with objects classified according to CoClass.

6 CONCLUSIONS

Presently, numerous different methods (over 100s) for delivering data in various data structures are used in the underground infrastructure industry. Among others, these include core drilling, geological mapping and geophysical data providing models and results often not supported by commonly used software in the design process. This means the full potential of a joint interpretation of all available data is set aside at different stages. To make an optimal use of all available data, a proper database and an efficient workflow is needed to communicate both data and models for all parties at all stages – from the geotechnical design team to the asset management stage. The GeoBIM concept is suggested as a concept for fulfilling a process, capable of efficient digital handling of all geotechnically related data from field to long time management. The end user will be able to access data via no other tools than the web browser. The core of the concept is the GeoBIM database, from which data can easily be exported for 3D modelling purposes, visualized in 2D/3D, or the metadata could be analysed, among others.

The GeoBIM concept has been implemented in four large infrastructure projects in Sweden and more than twenty smaller projects. The experience obtained suggests that the GeoBIM methodology should be considered as a state-of-the-art tool and a solution for communication of underground geo-data, models and interdisciplinary issues between parties involved in the design, management or the overview process in any underground infrastructure project.

In the near future, there is a lot of efficiency and preciseness to gain, if common data structures and exchange formats of all geo-related data properly compatible with CAD software are developed.

However, in a global digitalization perspective, the communication formats/methods/skills for a larger group of parties involved (stakeholders) than today must be developed, to make use of the full potential of geo-related data and models in a facility´s lifetime perspective. The development of the CoClass system for underground geo-related objects is such an initiative. In an ongoing R&D project a CoClass code system for geo-related underground space objects based on international standard ISO 12006-2 is suggested. As an example the top surface of a modelled clay layer has got the code A.AB01.UUB20. The purpose of developing the CoClass system for geo-related underground space objects is to make communciation of data and models between systems used by all involved parties in the design and building process more efficient. The time perspective is an LCC perspective for any infrastructure facility (> 100 years).

The geotechnical community should act better and proactively adopt and support further development and implementation of the CoClass system for geo-related underground space objects.

7 ACKNOWLEDGEMENTS

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