Proceedings of the XVII ECSMGE-2019
Geotechnical Engineering foundation of the future
ISBN 978-9935-9436-1-3

doi: 10.32075/17ECSMGE-2019-0890

XVII European Conference
ECSMGE 2019
Reykjavik
on Soil Mechanics
and Geotechnical Engineering

Recent developments with the use of the BIM method in Europe

Développements récents de l'utilisation de la méthode BIM en Europe

C. Kummerer
Keller Holding, Offenbach, Germany

S. Buddenberg, B. Böhle, C. Dudognon
Keller EMEA Division, Offenbach, Germany

ABSTRACT: The development of Building Information Modelling (BIM) in Europe is required by a number of governmental initiatives in Europe. This also involves geotechnical construction companies which therefore have to prepare for the participation in BIM projects. At the moment the development of geotechnical BIM models is at the beginning in comparison with BIM models of building structures above surface. The German construction industry published a paper to define demands of geotechnical construction companies on a geotechnical BIM model which is a big step forward to develop BIM in geotechnics. Keller is conducting BIM projects to implement the process and develop special tools.

RÉSUMÉ: Le développement du Building Information Modelling (BIM) en Europe est requis par de nombreuses initiatives gouvernementales. Cela concerne également les entreprises de la construction géotechnique qui doivent se préparer à participer à des projets en BIM. Le développement du BIM en géotechnique en est au stade préliminaire pour le moment, comparativement aux modèles BIM de la superstructure. Le domaine allemand de la construction a publié un article afin de définir quelles seraient les données requises par les entreprises géotechniques pour la mise au points d'un modèle BIM dans ce domaine, étape majeure pour le développement du BIM d'un point de vue de la géotechnique. Keller mène des projets BIM pour mettre en œuvre le processus et développer des outils spéciaux.

Keywords: Building Information Modelling, governmental BIM requirements, pilot project, data import

1 INTRODUCTION

Building Information Modelling (BIM) is undergoing a massive development in Europe at the moment. Despite different implementing strategies and timelines of the European states the goals of BIM are the same in every country: modernizing the civil construction industry, making building processes more efficient and create attractive jobs for future generations. With publication of the *public procurement directive* in 2014 by the European Parliament/Council, BIM is defined in article 22, paragraph 4 as new planning tool, the directive provides the possibility for EU members to require BIM for future public projects. The essential goals of BIM in general are the reduction of the

- construction and maintaining costs,
- environment impact and
- construction time.

The focus of BIM is to gain an additional benefit for building owners, but also a general improvement of the value-added chain. At the moment the application of BIM is mainly requested by public clients.

A core element of BIM is the cooperation via a digital building model (‚digital twin‘) which is used during the whole lifecycle of a building from early concept to asset operation stage including demolition. Due to aspiring to a close cooperation of stakeholders (e.g. designers and construction companies), design activities are anticipated to an earlier project phase. Consequently, one has got a bigger freedom of action to avoid expensive changes during subsequent construction phases.

Suitable software solutions allowing an efficient handling have been developed in the past for the building itself, while the subsoil and related works (ground improvement, heavy foundation) have been more or less neglected. This also concerns the determination of necessary demands on information for geotechnical works.

At the moment there is no integrated open concept for soil-modelling and linking relevant data for design. Beyond that there are no standardized elements for geotechnical works (i.e. bored piles with widened base) embedded in available BIM software. Also the open data format IFC (Industry Foundation Classes) provides geotechnical elements only rudimentary.

In chapter two of this article a short overview of the current development state of BIM on the three biggest European markets, the United Kingdom, Germany and France, will be given from a geotechnical construction company‘s view. The initiative of the geotechnical works department of the *German Building Industry Association* is emphasised especially. In a position paper the association already formulated in particular the demands on a geotechnical BIM model. In chapter 3, current BIM pilot projects of Keller which are used to test BIM use cases are presented.

2 STATE OF BIM DEVELOPMENT IN TOP 3 EUROPEAN MARKETS

2.1 United Kingdom

The government of the United Kingdom developed intensively the digitization of the construction industry in the past. In the report *Construction 2025* by HM Government from the year 2013, a vision for the future cooperation of government bodies and industrial partners was formulated. According to the report, the competitive abilities of the construction industry shall be ensured at national and international level, but also the growth of this sector shall be stimulated. From this it follows that the efficiency regarding costs, time and environment has to be improved. One out of five identified fields of the vision concerns the transition of the construction industry into a more efficient and modern industry where BIM is the digital tool to successfully manage this transition. The British Standards Institution published the Publicly Available Specifications (PAS) on BIM. For the construction phase the document *PAS 1192-3* defines the management of information in a BIM project. This document is also often used as a reference outside of the United Kingdom if there are no other national standards. It contains an overview of the different BIM levels (cf. Figure 1).

While level 0 can be understood as traditional 2D drawings, level 1 already considers models and objects. The collaboration plays also an important role. “Advanced” BIM starts at level 2 according to *PAS 1192-2* and *PAS 1192-3*. Since April 2016, BIM level 2 is required for participating in public projects in the UK. This led to a significantly increased BIM use. Despite this, there are still challenges regarding the application of

BIM according to the *National BIM Report* by NBS.

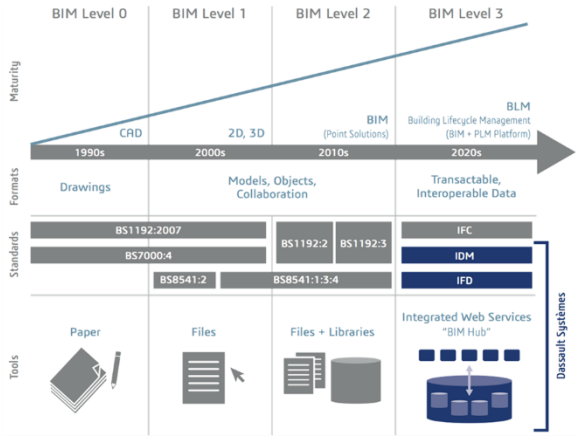

Figure 1. BIM level definitions according to PAS 1192-2

2.2 Germany

In Germany BIM is also seen as a major innovation driver to increase the efficiency within the construction industry. The chance to avoid faulty designs and to achieve a cost reduction especially for big projects could be a benefit of using BIM. In 2015, the German government published the *Road Map for Digital Design and Construction* which aims at a mandatory use of the BIM method for infrastructure projects by 2020 on BIM level 1 in Germany.

BIM level 1 according to this roadmap means in particular that public clients need to define specific requirements on the data to be delivered (i.e. level of detail and data formats) and that a BIM 3D model specific for every profession taking part in the project has to be used where one can deduce every necessary information. From 2020 on, contractors need to proof their ability to work with this method. Having this in mind, it has to be expected that also construction companies which offer special geotechnical works need to be prepared to be ready for BIM in Germany.

To position the role of geotechnical construction parties involved in the BIM process and to support the development of BIM in geotechnics on the German market, the Construction Industry Association via its specialist geotechnical section published the position paper '*BIM im Spezialtiefbau'* (BIM for special geotechnical works). This paper is only available in German at the moment, but will be available in English soon. With this, major requirements on the geotechnical models are defined from the view of geotechnical construction companies. These are in particular the possibility of

- checking the model for collisions with subsurface structures,
- deducing 2D drawings and schedules of geotechnical works,
- calculating quantities and linking qualitative data (i.e. concrete quality) with the bill of quantities for costing and also
- having a bidirectional data exchange between BIM model and structural analysis.

Furthermore according to the paper the design model should be used for visualizing remaining elements in the soil. Only if tolerances were violated or additional actions were undertaken, a separate as-built model should be delivered. With these general demands on a geotechnical BIM model the biggest geotechnical contractors on the German markets committed to BIM and positioned themselves clearly.

To be able to implement these defined use cases by using a BIM model, the definition of its content is crucial. An important step is the definition of geometrical and non-geometrical information for geotechnical products. Within the position paper, attributes i.e. for anchors like anchor type, anchor number, anchor level, anchor starting point, steel quality etc. are recommended. In Figure 2 the drawing of an anchor in the position paper is shown as an example for geometric definitions.

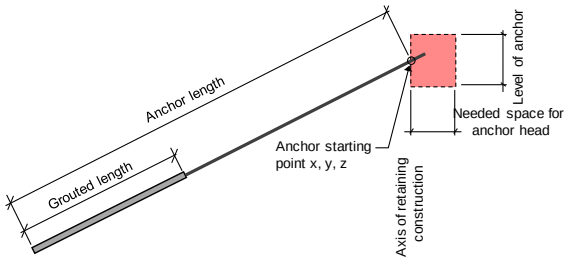

Figure 2. Geometric attributes of anchors according to the position paper "BIM for special geotechnical works" (re-drawn & translated according to position paper).

Since the definition of geotechnical elements in the open IFC format is only rudimentary at the moment, the proposed attributes of the elements in the position paper are a milestone to achieve a standardised BIM model exchange and also to develop the IFC format in terms of special geotechnical works.

A further essential content of a geotechnical model is the subsoil. Information about the soil, rock and ground water conditions is the basis of geotechnical design, construction and costing. According to the position paper, the soil model has to consist of a digital terrain model and soil layers with relevant data. An interface between software for creating building models and soil models is mandatory for this.

2.3 France

In 2015 a national strategy called 'plan de transition de bâtiment numérique' to promote the digitization of the construction industry was published by the French government. The *Operational Roadmap* encourages stakeholders to develop digital planning and construction tools for the construction industry and to conduct projects with the BIM method. Public projects are supported with a 70 mio € fund which shall take forward the development of digital methods in France.

Beyond this, BIM projects are also desired by private investors. The construction industry of France is aware of the new digital planning method and a long-term transition of the industry. From this it follows that the preparation of construction companies for BIM is crucial in France.

3 PILOT PROJECTS

3.1 General

Since the BIM method is expected to set a new standard in the future, a comprehensive implementation strategy is required. Pilot projects are a fundamental element in this implementation. With pilot projects the BIM processes and tools can studied and developed. For the projects described in this chapter the focus was on

1) risk management by means of gap detection,
2) quality management by importing machine and/or sensor data and
3) 2D-drawings generation for constructing.

Further pilot cases under development are on the use of a subsoil model, determining quantities with the BIM model and conduct cost calculations and laser scanning.

3.2 United Kingdom

Project description

For modernizing Victoria Station (Victoria Station upgrade – VSU) in the centre of London the southern hall of the station was refurbished and a new main station hall was constructed in the north. In addition, a new interchange tunnel (paid area link - PAL) and eight barrier-free entries to platforms on street level were realised in a densely build-up inner city area.

Geotechnical works for the new interchange tunnel had to be conducted close to buildings with highly loaded foundations and only little space to London Underground lines (cf. *Pandrea 2016* and *Kummerer 2018*). In some parts the District Circle Line is less than 3 m above the

new tunnel, Victoria Line situated at depth of 14 m. The new tunnel is situated in the transition zone from permeable river terrace gravels to the heavily overconsolidated London Clay. For securing the tunnelling, in total 2,500 Soilcrete jet grouting columns were executed to seal the soil and to improve the ground with a structural thickness of 1.2 m. The following boundary conditions had to be considered for design and construction:

- jet grouting elements very close to existing buildings,
- a high number of overlapping sub-surface structures,
- little space to busy London Underground tunnels,
- high demands on tolerances and
- executing jet grouting in the OC London Clay.

Model & use cases

Figure 3 shows the jet grouted columns, sub surface structures which had to be considered, the existing tunnel of Victoria Line and the new tunnel (PAL tunnel).

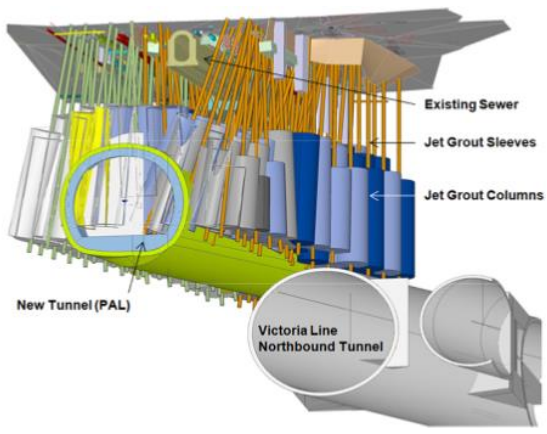

Figure 3. Soilcrete jet grouting columns and existing sub-soil structures

To achieve the demanding goals of the project the BIM method was decisive for success. The BIM model contained every information about the existing sub-soil structures and the data of the jet grouted columns which had been:

- GPS data for positioning the drilling rigs,
- measurement of bore hole deviations,
- production parameter of Soilcrete jet grouting multi stage procedure,
- verification of diameters.

By transferring these data it was possible for every stakeholder of the project to control the quality in time and to plan new actions if necessary. Due to this the tunnelling could be simulated before and jet grouted elements could be investigated for voids (cf. Figure 4, brown coloured elements).

The tunnelling could be finished successfully because of the use of the BIM method which offered the possibility for all involved parties to access a BIM model which could visualize all data in a comprehensive way. In addition it is mentioned that the model also was linked to the time schedule of construction works.

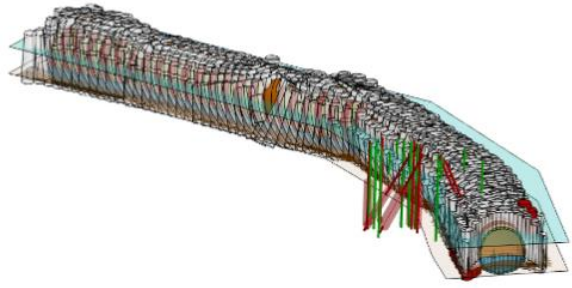

Figure 4. „As built"-BIM model with tunnel at VSU

3.3 Germany

Project description

For a new inner city buildings complex in Bonn including a tower with a height of 100 m an excavation pit on an area of about 19,000 m² with a depth up to 12 m had to be realised.

The soil consists of man-made fill of approx. 2.6 m followed by alluvial sediments (silt, clayey & sand, silty). At a depth of approx. 5 m younger

river terraces (mainly sand, gravely & silt/clay in-layers) can be found with a thickness of 11 m, underlain by older river terraces (gravel, sandy - sand, gravely). A highly weathered base rock is present at a depth of 24 m.

The decision was made to construct a slurry wall with a thickness of 60 cm and a perimeter length of about 480 m with anchors in two and three rows, respectively. The slurry wall was structurally designed as a soldier pile wall with steel profiles in a distance of approx. 2 m. On a length of 120 m, the retaining wall was secured by a secant pile wall. A grabber with a width of 3.40 m which was equipped with Jean-Lutz sensors was used for excavations for the slurry wall. The project was mainly used for creating a BIM model and to test the import of sensor data from the grabber for visualizing deviations.

Model & use cases

The BIM model was created within the scope of a master thesis which was done in cooperation with the university of Duisburg-Essen (cf. *Wollschläger 2018*). Revit 2018 was used to create the model while the definition of the elements was done under consideration of the position paper mentioned in Chapter 2. The BIM model is shown in Figure 5.

Within the master thesis the model was also experimentally used to link quantities and qualitative data with a bill of quantities using RIB iTWO 5D which worked properly. The experience gained within the thesis can be used for future projects.

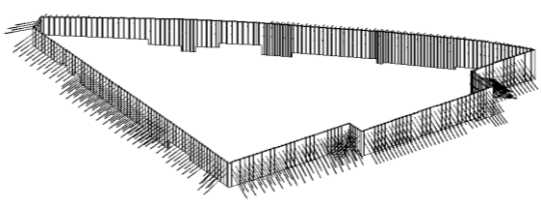

Figure 5. Isometric view of the BIM-model in Bonn, Germany

The model was also used afterwards as a basis for the import and visualization of machine data. The sensor data provide values of the absolute shift of the mid-point in x and y-direction (in-plane) per excavation step in depth z. In addition the rotation per step in depth is given. An example of the table based sensor data is shown in Figure 6.

Prof(m)	DX(mm)	DY(mm)	Z(d°)
3,00	0,000	0,000	0,000
3,07	-0,020	0,010	0,000
3,14	-0,030	0,010	0,000
3,21	-0,030	0,010	0,000

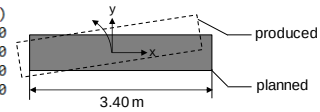

Figure 6. Example of Jean-Lutz sensor data (left) and schematically illustrated excavation deviations (right)

The slurry wall lamellas were constructed with at least two overlapping excavation steps while sensor data was available for each single excavation trench. Since the original BIM model did not contain the excavation steps of the grabber, they had to be added manually afterwards. For an import of sensor data, Keller uses the API (application programming interface) of Revit to create own suitable plugins for Revit. With the tool created for slurry walls one can import a table based readable file by clicking on an excavation step and selecting the belonging file. The import plugin will then create an own element for every step in depth or row in file, respectively. The result of the visualized excavation deviations in Revit is shown in Figure 7 with 20x amplification (left) and without amplification (right). Note that all tolerances were met.

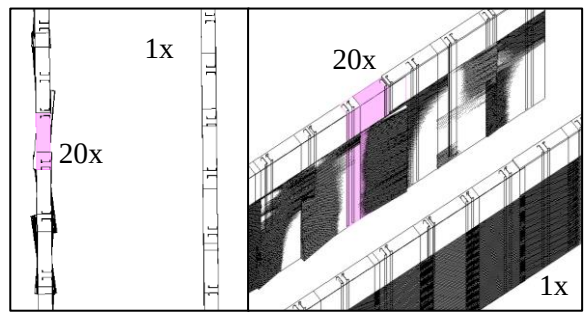

Figure 7. Top view (left) and isometric view (right) of d-wall with 20x amplification of deviations and 1x amplification.

As a result the visualization of the actual produced geometry is obtained for slurry walls in Revit and therefore it is possible to conduct enhanced quality management checks. Since every excavation step has to be modelled in addition the effort is relatively high. But if the high tolerance standards have to be met, it can make sense to visualize the deviations in an as-built model to plan new actions if necessary.

3.4 France

Project description

Alongside the canal de la Deûle in Santes, France, a logistic storage building with an area of about 41,500 m² is under construction starting in 2018. Up to a depth of about 7 m, unstable silt was found followed by a sandy layer with a thickness of about 8 m before a compact chalk layer was reached. Such a soil configuration under heavy loads would result in excessive settlement. Thus, ground improvement by rigid inclusions was selected for ground improvement. About 7,300 rigid inclusions, in a 2.5 m x 2.5 m grid with a length of about 10 m, is installed under the slab. A lime-cement load transfer platform of 40 cm has been prepared between the slab and the rigid inclusions. Under the rest of the foundations (mainly single footing), rigid inclusions were installed without a load transfer platform directly in contact with the foundations.

The project has been done completely with the BIM method. For the ground improvement actions an own BIM model in Revit and IFC format was required by the client. According to the BIM execution plan (BEP), the execution drawings had to be deductible from the BIM model. Besides the design model the client also required an as-built model. The BIM models of every stakeholder were dropped and exchanged via an online platform.

Model & use cases

To create the BIM model of the ground improvement, the model of the foundations and its base point coordinates had been decisive. Based on this model, the rigid inclusions were created, placed and named. The category of this elements in Revit was chosen to be *generic model* to not collide with other lots of the project. Via a newly created Revit import plugin for columns, piles and comparable elements the production data – actual depth and concrete consumption – were imported into the model automatically. This model was then given to the client in addition to the design model. The BIM model of the rigid inclusions is shown in Figure 8 in isometric views and top view. The BIM model of the foundations – which is linked in Revit for this view – contains the draft design state of deep foundations which can be seen in closer view in Figure 8.

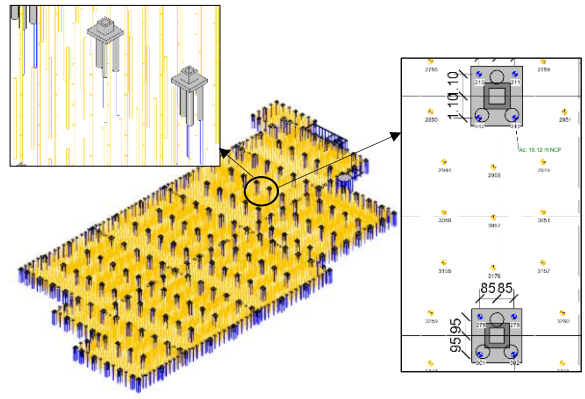

Figure 8. Isometric & top views of BIM-models foundations and rigid inclusions - blue: rigid inclusions below foundations, yellow: rigid inclusions below slab, grey: foundations

Data quality and handling is has a significant influence on the efficient further processing.

4 CONCLUSIONS

Because of several governmental initiatives in Europe to establish BIM, a momentum for this digital collaboration method can be observed creating the demand for comprehensive preparation also for geotechnical applications. Therefore own BIM capabilities have to be developed timely.

This can also be used as a chance to improve the efficiency and quality of existing processes.

On the other hand, the development of BIM in geotechnics is at the beginning, so a lot of development and implementation work has still to be done, especially standardizing the processes and tools. Standardised geotechnical BIM elements are needed to ease the exchange of information on basis of the BIM method. Adding geotechnical information to the BIM model can be a huge advantage for owners during the design and delivery phase. By running pilot projects in the BIM introduction phase, a smooth transition into the digital construction era is facilitated.

5 REFERENCES

European Parliament 2014. Directive 2014/24/EU of the European Parliament and of the Council of 26 February 2014 on public procurement and repealing, Directive 2004/18/EC.

HM Government 2013. Construction 2025 – Industrial strategy: government and industry in partnership. United Kingdom.

British Standards Institution 2013. BSI PAS 1192-2: Specifications for information management for capital/delivery phase of construction projects using building information modelling. United Kingdom.

British Standards Institution 2013. BSI PAS 1192-3: Specification for information management for the operational phase of construction projects using building information modelling. United Kingdom.

NBS 2017. National BIM Report. Newcastle upon Tyne, United Kingdom.

Federal Ministry of Transport and Digital Infrastructure 2015. Road Map for Digital Design and Construction. Berlin, Germany.

Hauptverband der Deutschen Bauindustrie e.V. Bundesfachabteilung Spezialtiefbau 2017. BIM im Spezialtiefbau. Berlin, Germany.

French Government 2015. Plan de transition numérique – operational roadmap. Paris, France.

Pandrea, P., Essler R., Marsden, P. 2016. Victoria Station Upgrade – Protection of Sensitive Structures during Tunneling. *World Tunnel Congress: Proceedings*.

Kummerer, C., Zöhrer, A., Böhle, B. 2018. BIM-Erfahrungen als Spezialtiefbauunternehmung bei Infrastrukturprojekten in Großbritannien und Kontinentaleuropa. *Digitale Infrastruktur und Geotechnik: Proceedings* (Ed: Grabe, J.), 217-228. Institut für Geotechnik und Baubetrieb, Hamburg, Germany.

Wollschläger, M. 2018. Entwicklung und Untersuchung eines 5D-Baugrubeninformationsmodells. Master thesis at the University of Duisberg-Essen in cooperation with Keller Grundbau GmbH. Essen, Germany.