Role of Geotechnical Engineering in BIM process modelling

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Abstract. BIM “Building Information Model” creates a significant step forward in the whole process of construction. The role of geotechnical engineering will be shown as for classical building engineering so for civil engineering structures. In the first case all upper structures are in interaction with ground (subsoil), when foundation structures are basic element of this interaction. The 3D Ground model and 3D Foundation structure model create therefore one of the first individual parametric elements around basic (coordinating) BIM model. Some specificity will be shown as the impact of step by step creation (nD dimension) of the Ground model for the earliest building conception. Roughly the same is valid for civil engineering structures. Some specificity will be shown for earth structures of transport engineering, as a selection of borrow pit, definition of soil compaction for fill, fill compaction or any other methods of soil improvement and its control as they create important elements for the safe and optimal embankment design and performance. Final 3D Ground model together with 3D Geotechnical structure model (real performance) create the important base for the future decision making, when some changes will occur.

1. Introduction

BIM – Building Information Modelling process is in principle reacting on up to date demands on digitalization increase - demands that are connected with terms as Industry 4.0, respectively with Construction industry 4.0. One from the different definitions of BIM term is: BIM is shared (shareable) source of knowledge about a certain facility creating confidential base for decision-making process during all of its life time cycle – defined from the first conception up to its demolition, [1]. In other words, BIM is a tool for optimization of all phases of the construction process, starting from preparation, design, realization up to long-term operation, including mutual interconnection of these phases. First publications in the discussed problem show on increasing interest in this field, e.g. [2, 3, 4, 5].

For harmonization of the BIM process internationally, there exists EN ISO 16739 “Industry foundation classes (IFC) for data sharing in the construction and facility management industries” published in 2013 and revised in 2018. According to the abstract to this code – ISO 167 39 represents an open international standard for BIM data that is exchanged and shared among software applications used by the various participants in a building construction of facility management project.

Nevertheless, the utilization of BIM process is different in different countries. For example in the Czech Republic the government in its decree: “The concept of implementation BIM method in CR” from 2017 stated:
- With the help of cooperation improvement, information sharing and culturing of individual relationships to contribute to the higher effectiveness of civil engineering projects;
- All large contracts financially supported from the public money should be set in BIM regime from 2022.

Nevertheless the role of geotechnical engineering in BIM process modelling is the same for different countries and therefore some specificities are discussed further.

2. Basic position of geotechnical engineering in BIM process

As was already mentioned, data standard is based on the open data format IFC that is playing basic role. This role consists from the solitary coordination model of structure, which is composed from individual construction files, operation sets or engineering objects. This data format helps to the coordination of fragmental models, for collision detection, for display of the whole building construction, individual stages, for creation of demanded cross sections etc. 3D computerized model of building construction (or civil engineering structure) is the fundamental element of the BIM process. However, this 3D model is enriched by supplemented information, as about time, financial expenses, construction maintenance etc., which can be denoted as 4D, 5D, generally nD models.

Basic difference between geotechnical structures and other structures is the construction material. Ground properties are nonhomogeneous, corresponding to natural material, strongly changing with position and theirs determination are connected with large uncertainties. The designer of geotechnical structure is responsible for determination of so-called representative values of the geotechnical parameters and so the step-by-step improvement about ground properties with time is extremely important process. While for structures from man-made materials as steel or concrete, the producer can guarantee their properties with high credibility. Therefore, the risk connected with geotechnical structures is much higher than for structures from man-made materials. Risk reduction for geotechnical structures is first depending on the geotechnical (ground) investigation, for higher risk should be much more detailed. Similarly, the care devoted to the design is directly proportional to this risk. The linkage between different steps (phases) of the Geotechnical (Ground) investigation (GI) and steps (phases) of the Geotechnical design (GD) are part of Table 1.

Table 1. The linkage between different steps of the Geotechnical investigation (GI) and steps of the Geotechnical design (GD)

| GI                          | GD                                      |
|-----------------------------|-----------------------------------------|
| Desk study                  | Study – investment project (idea)       |
| Preliminary GI              | 1st step project – documentation for planning inquiry |
| Design (detailed) GI        | Design (GD report) – documentation for building permit |
| Supplementary GI            | Design modification – for construction |
| Confirmatory GI             | GCR - Geotechnical construction report – real structure performance |

Step-by-step process is specific for Geotechnical structures and creates a significant part of the BIM model. All partners of the construction process (investor – owner, persons responsible for the GI, designer and contractor) should cooperate to guarantee that:
- The investigation methods are respecting the structure significance and risk;
- Areal and vertical distribution of investigation points (boreholes) is reflecting the area influenced by the new structure;
- The range of the lab and field tests makes it possible for theirs credible evaluation of the solved problem.

At the end of whole process the differences between measured results, selected representative results and results obtained during last two steps of GI can be evaluated, whether the approach to the
geotechnical parameters was optimal, or so conservative, respectively so optimistic. This back analysis is important for the similar case in the future.

As the geotechnical structures can be divided into 3 main types:
- Foundation structures – construction on ground,
- Earth structures – construction with ground,
- Underground structures – construction in ground,
the next part is focused in this direction.

2.1. Building engineering structures - foundation structures

All structures are in close interaction with ground. For buildings, the load of superstructure is transferred into ground via foundation structures. Superstructure, foundation structure and ground create together one unity – structure – Figure 1. In this case the fragmental model of the ground together with foundation structure creates an un-substitutable role in whole coordination of BIM model. The position of the fragmental model of the ground together with foundation structures is displayed in Figure 2. That the up to day reality is little bit different is obvious, 3D model of superstructure is displayed very often without this fragmental model. The utilization of the BIM model can play very significant role in this direction. Any model of superstructure cannot be situated at all types of ground (place). For different ground, the different foundation structure should be proposed.

![Figure 1. Structure definition. Interaction of superstructure with ground.](image1)

![Figure 2. The position of geotechnical structure in BIM model. Geotechnical structure creates an individual parametric element around basic BIM model.](image2)

The above-mentioned problem can also be solved with the support from the side of the Eurocode 7 Geotechnical design. There exist a close conformity between basic phases of the geotechnical structure design and execution according to EC 7 with fragmental models of geotechnical structures in the BIM model:

- Ground model – geological, hydrogeological models of the subsoil together with the results of the lab and fields tests of the geotechnical parameters obtained directly or indirectly.
- Geotechnical design model – containing of representative (characteristic) values of the geotechnical parameters – selected, substantiated by designer and consequently applied in the next phase.
- Calculation model during which limit states are checked either by analytical or numerical calculation models with utilization of parameters specified in the previous phase.
- Model of the real structure performance.

BIM model can also help with cooperation of all partners during an execution phase. Monitoring of ground water level (pore pressures) with time is important aspect for pit excavation with slopes. Also the monitoring of retaining elements which are guaranteeing vertical slopes of the pit is very important. Especially in the case when observational method of the design is selected. E.g. for pile retaining wall all partners can find which new piles were added each day, together with information about their performance. This information can help to create 4D, 5D, generally nD models with respect to cost and progress charts.

During the superstructure lifetime, the final fragmental models of the ground with foundation structures can be used when loading from superstructure will be increased, when ground and foundations will be used for new superstructure or when some interaction with new neighbouring structure will need to be solved.

2.2. Civil engineering structures – earth and underground structures
Geotechnical structures like dams, transport embankments, sanitary landfills, tunnels, underground repositories create the basic element with much longer lifetime expectation compared to other elements. For example tunnel lining is this basic element and security system, ventilation are these others with much shorter lifetime expectancy. Earth structures need not only ground model of the subsoil, but also ground model of the borrow pit from which material is used for the embankment construction, Figure 3. Therefore, the earth structure or underground structure can create a solitary coordination model in BIM model, around which are fragmental elements Figure 4.

Some advantages of the BIM model for transport infrastructure embankment are presented in Figure 5. There is the final model of the ground together with constructed embankment compacted in individual layers, including subsoil improvement (vertical drains) and embankment reinforcement (with geosynthetics reinforcing layers). Geological model in 3D makes it possible to state that investigation points (boreholes) are covering with adequate preciseness the area of ground, which is affected by constructed embankment not only in cross section but also in longitudinal direction. For each investigation point there is an in-reference where are stored information about time of performance, technical details, collected samples, results of testing etc. Similar in-references are to the disposal for vertical drains and reinforcing geosynthetics. For compacted layers the method of compaction control denoted as CCC – continuous compaction control (or intelligent compaction) is preferred as giving continuous information about compaction results.
Figure 3. Sequence of the main phases influencing overall risk within the logical scheme of the GDR for Earth structures.

Figure 4. The position of geotechnical structure in BIM model. Geotechnical structure creates a basic BIM model.
As already mentioned for retaining walls used in the case of building foundation, similar 4D, 5D models can be created for embankment execution, giving information about progress and financial charts at selected time (day) to the all partners.

The owner of civil engineering structures is an administrator of the final BIM model and utilizing it in the case of any changes, which can be expected during the structure lifetime. Starting from the phase of structure maintenance and improvement, over any future interaction as are new structures in the vicinity, interaction with natural hazards (e.g. with floods, landslides, earthquakes) or interaction with man-made accidents (fire, accidents of lorries carrying chemical products etc.).

3. Conclusion

For geotechnical engineers the acceptance of BIM model is a great chance. In the first place, this acceptance can help to the optimization of geotechnical investigation, design and structure execution according to the risk, with which such structure is connected. Therefore basic principles of BIM were presented as well some differences between foundation structures on one side and earth and underground structures on the other one.

For geotechnical structures the cooperation between all construction partners, information sharing and culturing of individual relationships is bringing advantages primarily in following aspects:
- Step-by-step improvement about ground model, with optimal opportunity to select characteristic values of the geotechnical parameters as well with structure design;
- Structure execution documentation (including structure control and monitoring) leading to the fulfilling of all demands specified in the design.

Finally, the utilization of the BIM model of real structure execution by owner can lead to the optimization of structure maintenance or reconstruction with better ability to react on any interactions with which existing structure can be affected in the future.
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