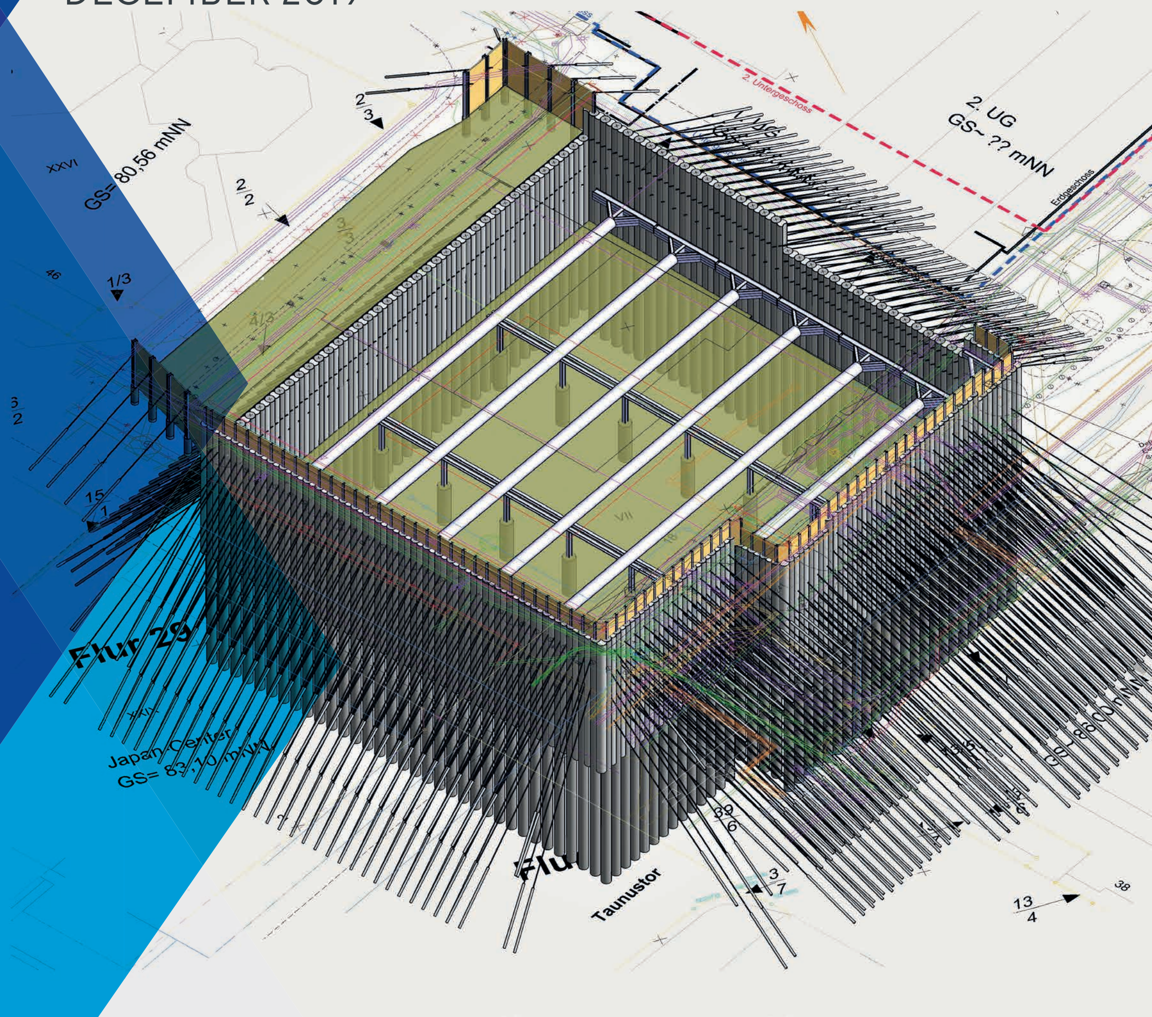
BAU INDUSTRIE

BIM IN GROUND ENGINEERING

TECHNICAL POSITION PAPER OF THE FEDERAL DEPARTMENT OF GROUND ENGINEERING IN THE GERMAN CONSTRUCTION INDUSTRY FEDERATION (HAUPTVERBAND DER DEUTSCHEN BAUINDUSTRIE E.V.)

DECEMBER 2019



INITIATIVE

The rapid advance of digitalisation will profoundly change the way work is conducted in Germany in the design, construction, and operation value chains. The Road Map for Digital Design and Construction for the Public Sector issued by the German Federal Ministry of Transport and Digital Infrastructure (BMVI) has defined the guiding principles until 2020 and beyond.

A key component of any successful implementation of the BIM methodology (Building Information Modeling) includes a clear definition of the requirements (data, processes, skill levels), quality features and interfaces, as well as cooperative partnerships. All parties involved in construction are therefore called upon to participate promptly in the currently ongoing coordination and regulation process.

The German Federal Department of Ground Engineering intends to make an active contribution to this process with this position paper. We consider this to be particularly important because our specialised set of skills - although it constitutes an important link in the severely fragmented value chain - is presently not being given the requisite level of attention. However, the BIM method can only be implemented successfully if the entire process functions and the parties involved in a construction project understand their tasks and perform them in a collaborative manner.

This position paper aims to:

1. Define the requirements within the BIM process in respect of other parties involved in a construction project (including the client and the designers)
2. Define the interfaces to other parties involved in a construction project
3. Define which data should be supplied
4. Expand and specify in more detail the often very general definition of BIM within the construction process

This issue (December 2019) of the position paper is a revised and expanded version of the first issue published in December 2017.

Due to dynamic developments concerning the BIM topic, this position paper is not conclusive and is subject to further revision.

CONTENT

1 INTRODUCTION

Building Information Modeling (BIM) is a new integrated design and execution method in the construction industry. Its aim is to execute all design and construction processes based on a digital building information model. The components of a building are not just described in purely geometric terms in this case. Their descriptions also include additional product-related information (material, manufacturer designation, etc.). In contrast to the media discontinuity that characterises traditional project processing methods, application of the BIM method leads to the gradual and continuous collection of information over the entire life cycle of a building. By linking previously decentralised data sources such as time schedule design (4D) and cost estimate (5D) in this model, all participants involved in the project have access to a full set of the information that can then be used to conduct more extensive simulations and analyses.

To obtain clear results using the BIM procedure, one needs to start out with clear, project-specific definitions in terms of the geometric and product-related details of the model and components. In most cases, this is achieved in the framework of BIM processing plans or modeling guidelines. The modeling depth and the definition of building properties depend primarily on the subsequent use of the BIM application scenarios, analyses, and the simulation (see Figure 1).

The aim of this position paper is therefore to illustrate the requirements for technical models of ground engineering from the viewpoint of future consumers who will use this model data, in this case the ground engineering companies in Germany that are executing the construction work.

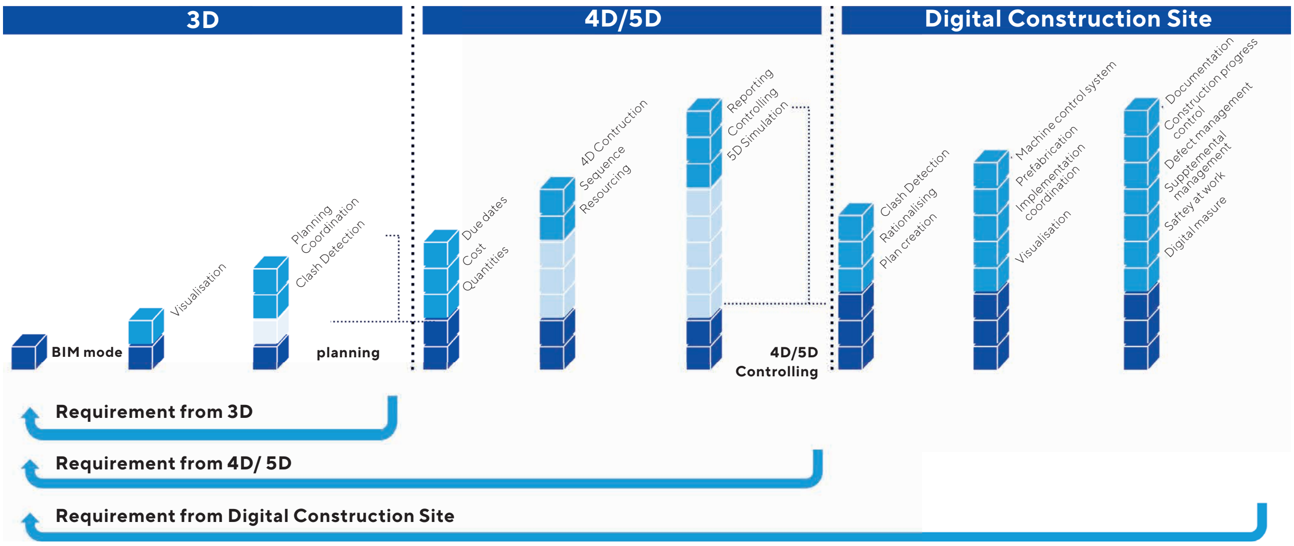


Figure 1: Requirements for the vertical scope of modeling and the characteristics of object properties based on BIM application scenarios

2 BIM APPLICATION SCENARIOS IN GROUND ENGINEERING

The application scenarios (AppS) of the BIM in a project will be agreed to on the basis of the BIM objectives, specifically in the BIM Execution Plan (BEP), and on the Employer's Information Requirements (EIR).
The implementation of the application scenarios is a complex process based on various digitalisation tools and requires the active participation of everyone involved in the project. This means in particular that all parties involved shall have access to the necessary information when it is needed, and that this information meets the required level of quality. The client shall create the conditions required to achieve this. The more comprehensively the application scenarios are to be implemented, the more comprehensive all organisational, technical, and contractual requirements and measures will need to be.
Some of the conditions necessary for fully comprehensive implementation of certain application scenarios have not been created yet, but some aspects can already be implemented today.

The application scenarios relevant to ground engineering were derived based on the BIM4Infra2020 application scenarios (04/2019) and are described in the following. Other application scenarios could be conceived in the future.

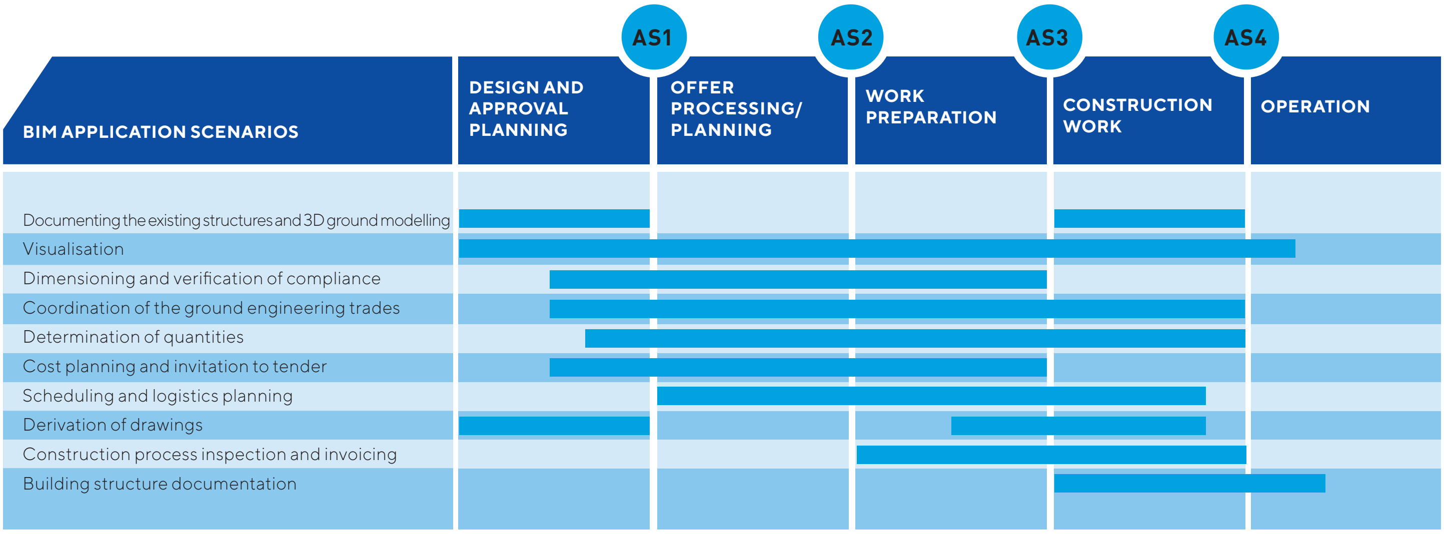


Figure 2: BIM Application Scenarios in Ground Engineering

2.1 DOCUMENTING THE IN-SITU STATUS AND 3D GROUND MODELING

In the technical model of the existing structures (e.g. for use as a basis for clash detection or a ground settlement evaluation) all relevant above-ground and underground structures currently existing (buildings, underground pipelines, infrastructure, wells, remaining installations, etc.) are documented. This input data can be obtained from existing documents, surveys, and laser scans.

The in-situ status also includes the ground at the site. Since interactions between the ground engineering works and the surrounding soil play an important role (e.g. in the selection of the method or of the locations of components), a separate technical model of the ground is required. Responsibility for continuation of the technical model ground must be defined in advance in the EIR and in the BEP.

The requirements on these two partial models can be found in chapter 4.

2.2 VISUALISATION

An appropriate visualisation based on the BIM model is used as an understandable basis for project meetings, meetings with customers, and public relations work. Visualisations lead to clear communication and serve as a basis for making decisions. Depending on the exchange scenario, it is possible to directly display the product information and the data from the manufacturing process, for example the status or deadlines. Input data for the visualisation includes current model states, a material library that includes visual properties, as well as product and process data.

2.3 DIMENSIONING AND VERIFICATION OF COMPLIANCE

The model should provide access to the input parameters (geometrical parameters, geology and soil characteristics, ground water levels, etc.) required for structural (geotechnical) design prior to ground engineering works. The aim is to have design results that can be traced back to the model.

2.4 COORDINATION OF THE GROUND ENGINEERING TRADES

The ground engineering trades should be coordinated based on a model-based clash detection test. The technical models are collected in a coordination model and then subjected to a (semi-) automated clash detection and systematic conflict resolution process. „Clash detection" in ground engineering must be carried out for the final state as well as for temporary conditions. Areas of overlapping and the required minimal distance to each structural element (e.g. anchors), or to existing components (underground pipelines, existing buildings, etc.) shall also be taken into account in compliance with the construction tolerances and based on the construction equipment used (e.g. the anchor drilling rig).

2.5 DETERMINATION OF QUANTITIES

It shall be possible to derive quantities and lists of components from the model. For this purpose, the geometric properties and other properties of those elements need to be evaluated. It shall also be possible to evaluate specific requirements relating to the process of determining quantities for ground engineering, e.g. consideration of temporary conditions (e.g. over-cut) and the interaction between different elements (e.g. for layer-related determination of quantities). The determination of quantities can be conducted in various phases and for various tasks, with output in the form of lists for further usage (invitation to tender, cost estimation, preparation of work, etc.).

2.6 COST PLANNING AND INVITATION TO TENDER

BIM models can be imported into a tender, contract award and accounting software, e.g. to determine quantities or to conduct nominal-actual comparisons and provide progress reports.
Other properties (attributes) may also need to be assigned to the components in the design software. Quantitative properties specify items such as lengths, surfaces, and diameters.
The qualitative properties describe the properties of the construction materials (e.g. concrete class C30/37, percentage of reinforcement, etc.) For this purpose, a unique identification code shall be assigned to the components in the design software using a uniform classification system to enable correlation between the building components and the scope of work defined in the bill of quantities. For this reason, a uniform classification system was developed (see section 5.1 "Classification" for more information). This should enable automatic linking of the quantities in a model-based cost estimate. Lump sum items containing several subtasks that arise at different times in the construction process make targeted application of the BIM more difficult. As a result of the lack of unique associations between a model element and a position in the bill of quantities, it is impossible to obtain a clear and realistic model in terms of the costs as well as in terms of the process (place, time, and flow of resources). Instead, billing units should be selected that can be derived from the technical model at the component level (e.g. separate pile and anchor units instead of a complete bored pile retaining wall).

2.7 SCHEDULING AND LOGISTICS PLANNING

BIM models shall be linked to a schedule to enable the creation of simulations of the construction progress. The tasks in the schedule are assigned to specific elements of the model for this purpose. The schedule is based primarily on construction sections (e.g. lots), on the types of retaining walls and foundations, anchor layers, excavation levels, and external time constraints (e.g. traffic phases). The link can be made at various levels of detail, e.g. at the component group level (e.g. pile wall) or for individual components (e.g. pile, anchor, inserted I beam, D wall panel).
On this basis, it is possible to identify spatial and time-related conflicts, conduct variant comparisons, and check the plausibility of service approaches to check the general practical feasibility of the building structure and to optimise the construction sequence.

2.8 DERIVATION OF DRAWINGS

To derive detailed 2D - drawings directly together with all the necessary lists (lists of coordinates, material lists, drilling tables, etc.) from the technical model, that model must possess a sufficient level of detail (cf. section 4.4). If necessary, non-modeled details or standard details shall be added to the detailed design drawings.

2.9 CONSTRUCTION PROGRESS INSPECTION AND INVOICING

Deviations shall be identified promptly by documenting the current status of the construction process comparing it promptly to the as-planned status. The step-by-step determination of the finished construction and its digital documentation shall be documented continuously. This creates the basis for the building structure documentation as well as for invoicing the construction services.

The input data for the construction progress inspection are the time schedules, the models, and the construction dates. In this regard, it shall be ensured that the schedule, bill of quantities (BOQ), and model have the same structure and level of detail.

Quantities determined based on a model can be used as a basis for invoicing the construction services when the construction-specific invoicing rules are considered.

Input data for invoicing the construction services are previous determinations of quantities as well as a construction progress inspection conducted during the invoicing period being examined.

2.10 BUILDING STRUCTURE DOCUMENTATION (AS-BUILT)

If project documentation is required for the components remaining in the ground in the form of a 3D technical model, the corresponding components are displayed with their planned geometry and location unless otherwise agreed to. Deviations are then only incorporated in the model if the construction deviates from the contractually agreed to tolerances and/or if additional measures (additional anchors, seals, etc.) were required. Only the information relevant for the documentation of the individual components is attached to the existing model. The resulting attributes correspond to the definitions of the exchange scenario AS4 - AS-BUILT (cf. section 3.4). Additional, contractually agreed information shall be handed over in the form of digital documents.

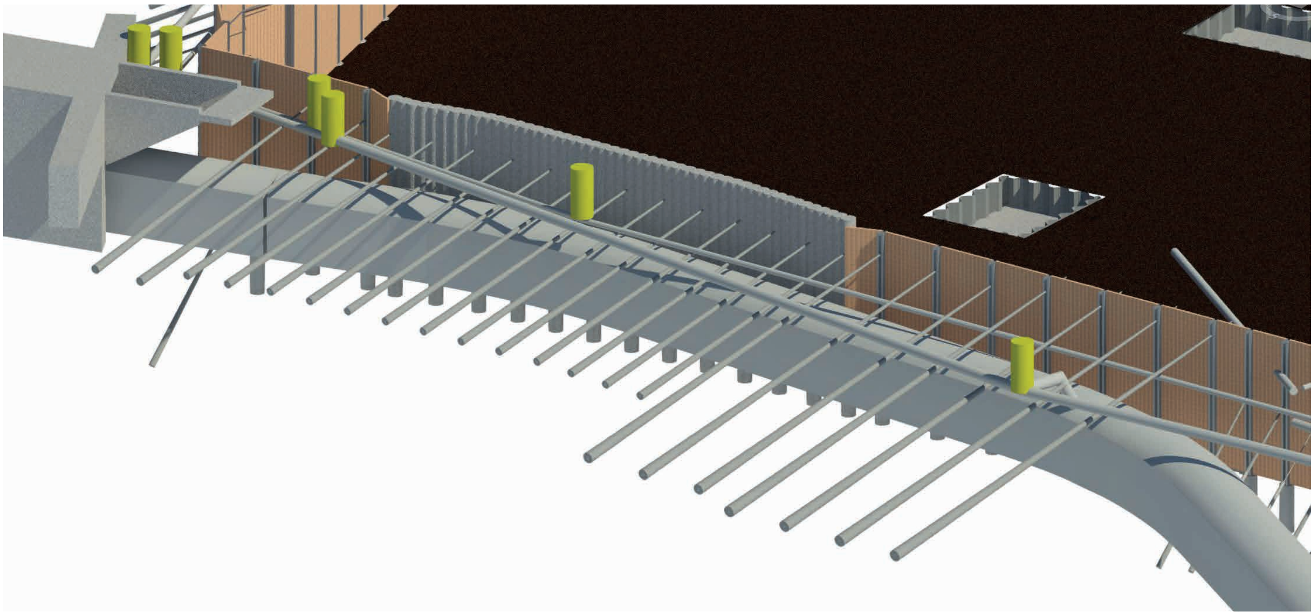


Figure 3: Example for the coordination of ground engineering trades

3 DATA EXCHANGE SCENARIOS

The following data exchange scenarios are defined to record requirements for model contents more clearly. The scenarios take the roles of the contracting authority, the designer, and the contractor into account. Further contractual relationships and roles are not considered in this position paper.

Clearly defined information requirements for the particular project are a prerequisite for the successful implementation of the data exchange. The data exchange requirements are defined by the customer in the context of the Employer's Information Requirements (EIR) and are updated in the BIM Execution Plan (BEP). However, minimum requirements are defined for each phase for the building information models to be handed over, see Appendix 2, "Minimum requirements for model elements". The exchange scenario AS1 defined in section 3.1 "AS1 - Invitation to tender" refers to the case of a detailed invitation to tender. In principle, the same minimum requirements also apply to other variants of the invitation to tender process, but they can be adapted to specific projects.

3.1 AS1 – INVITATION TO TENDER

Description	Delivery of draft design / invitation to tender documents by the contracting authority to the company as the basis for creating an offer.
Supplier	Contracting authority
Recipient	Bidder

3.2 AS2 – DETAILED DESIGN PLANNING

Description	Transfer of the detailed design plan from the designer to the contractor as the basis for construction work (as planned).
Supplier	Designer
Recipient	Contractor

3.3 AS3 – PLANNING OF WORKS

Description	Delivery of the planned works (as planned) as a supplement to the detailed design plan, to the extent required, by the contracting company to the contracting authority.
Supplier	Contractor
Recipient	Contracting authority

3.4 AS4 – EXISTING STRUCTURAL MODEL (AS-BUILT)

Description	Transfer of the existing model (as-built) from the contractor to the contracting authority. This corresponds to the as-built model in the framework of the tolerances.
Supplier	Contractor
Recipient	Contracting authority

4 REQUIREMENTS FOR MODEL CONTENTS

4.1 TERMS AND DEFINITIONS

4.1.1 Coordination model

The coordination model is a model comprising the technical and/or partial models and is used to coordinate design activities and as a basis for agreement.
Example: Coordination model: excavation pit

4.1.2 Technical model

The technical model contains the trade-specific information of the technical designers. The technical designers involved in the project therefore create at least one technical model, whereby the spatial interfaces and the project coordinates absolutely must be coordinated. To ensure a clear structure and for performance reasons, it can be advantageous to divide the technical model into individual partial models.
Example: Technical model: ground engineering

4.1.3 Partial model

The partial model forms a defined part of the technical model created by the technical designer. The technical model only needs to be divided into partial models when the circumstances of the project require this.
Example: Partial model: retaining wall

4.1.4 Object group

An object group is a group of several objects.
Example: object group bored pile wall

4.1.5 Objects

Objects can be represented as components of the structure, of the construction support structures, or as the equipment used in the construction process.

4.1.5.1 Component

A component is a geometric object that is part of the structure and which is stored together with other non-geometric (product-related) information.
An overview of the most common components used in ground engineering is provided in Appendix 2.
Example: Bored pile

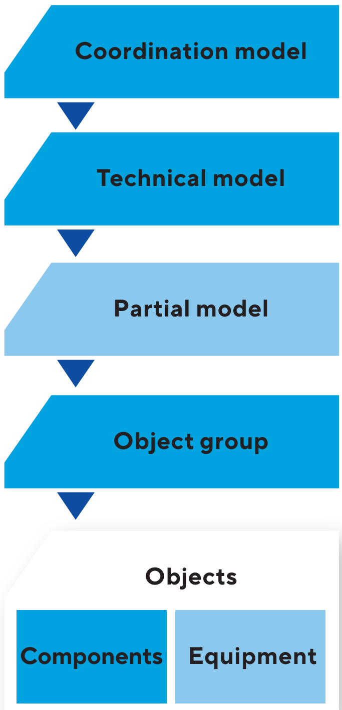


Figure 4: Model structure

4.1.5.2 Equipment

An equipment component is a geometric object that is needed to erect the structure, and which is stored together with other non-geometric (product-related) information. The equipment used at the construction site will not be considered for the time being in this position paper.
Example: Equipment crane

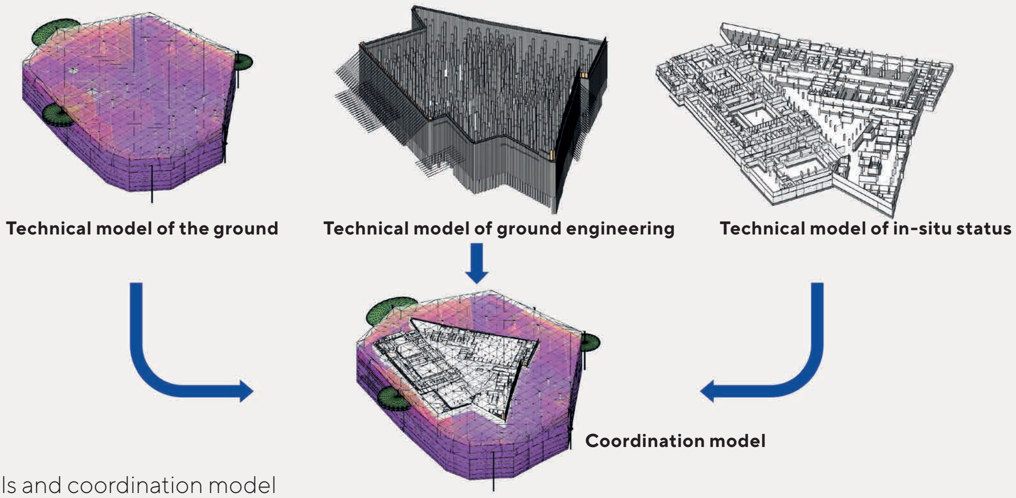


Figure 5:
Technical models and coordination model

4.2 TECHNICAL MODEL OF IN-SITU STATUS

The technical model must indicate the surroundings in which the construction project is situated. The project must be incorporated into the surrounding area. In particular, adjacent buildings must be illustrated together with the foundation situation, including any space constraints.
In addition, details of the following must be shown:

- Underground pipelines
- Existing buildings
- Properties (usage)
- Obstacles / artificial installations
- Safety distances
- Traffic situation
- Ordnance
- Protected areas

The level of detail of the 3D as-built structural model shall be selected according to the BIM application scenarios based on it.

4.3 TECHNICAL MODEL OF THE GROUND

All information describing the subsoil and the terrain are managed in a separate technical model, i.e. the ground model. This includes geometric data such as the elevation of the site surface and the location of specified fixed points in the terrain, as well as a partial model containing layer information and soil characteristics of the ground at the site based on the site survey. The ground model consists of the surface of the ground in the form of a digital terrain model and a ground layer model.

4.3.1 Partial model of the terrain (digital terrain model (DTM))

When manually surveying the site, it must be ensured that the points surveyed are 3-dimensional points in space in the digital diagram, which means the points must contain genuine z-coordinates, in order to ensure the ground model can be used later on.
Another method for surveying a site is the laser scanning method. Laser scanning provides a cloud of points containing a large number of points that need to be simplified prior to handover. To create the DTM, only use the points on the surface of the ground (ground points). The ideal point spacing is a maximum of 1 m (see Figure 6).

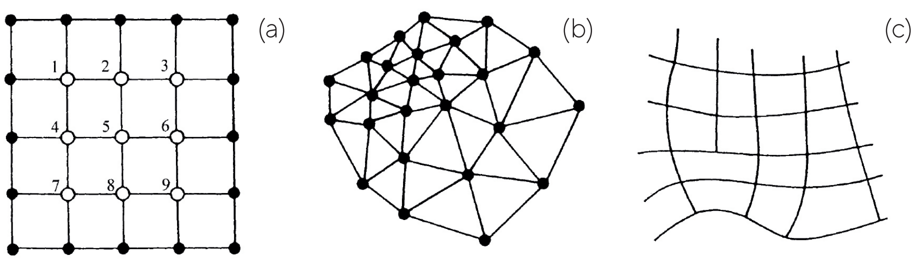


Figure 6: Methods of point meshing (a) grid (b) TIN (c) vector-based model; Source Wilson&Gallant, 2000

4.3.2 Partial model of ground layers

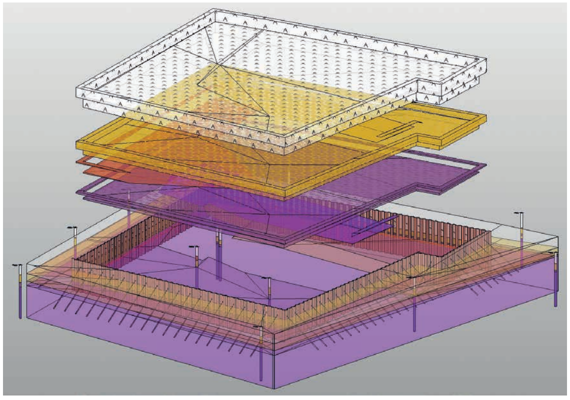
The ground layer model (GLM) is the digital representation of the geotechnical report. The geotechnical expert is responsible for creating the ground layer model. As well as an illustration of the actual layering, the underlying data in the layer model should also be/remain visible (boreholes, survey data, etc.) The characteristics of the layer boundaries between the drill profiles are simplified by applying suitable interpolation methods. Here, continuous as well as gradually thinning layers, inclusions, and lenses shall be illustrated together with the ground water level. Furthermore, it shall be possible to incorporate the DTM.
When using the GLM, it must be ensured that it is an approximation based on a limited number of point-like surveying boreholes.

It shall be possible to revise and update the GLM during execution of the project and as knowledge of the on-site ground conditions increases. A fundamental aspect is therefore the creation of an update concept for the GLM. The update concept should be developed in a collaboration between those involved in the project because everyone benefits from a consistent, current, and accepted ground model and because it is generally used as the basis for various processes.

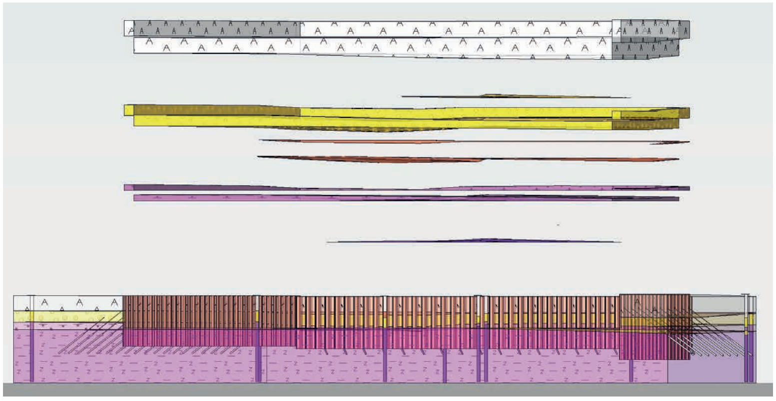
It should answer the following questions, among others:

- Which data will be updated (geometry, product-related information)?
- How are different versions stored and documented?
- Who is allowed to make and approve changes?
- In what time frame must changes be entered in the model and approved?

Furthermore, to take ground layering into account in the geotechnical calculation, it should be possible to inquire about the construction site layering at any location across the entire site.
For use in structural (geotechnical) calculations or the selection of a suitable construction method, the layers must contain information from the geotechnical investigation. This includes soil characteristics such as the friction angle, cohesion, density, and other results based on laboratory analyses.



Isometric



Cross-section

Figure 7: Example of an excavation pit coordination model with a ground layer model

For the model-based determination of ground masses, a volume model (generated from the layer model) must be linked and combined with a corresponding technical model (retaining wall, structural work/tunnel, etc.) (see figures 8-9). Corresponding interfaces between the software products used are essential.

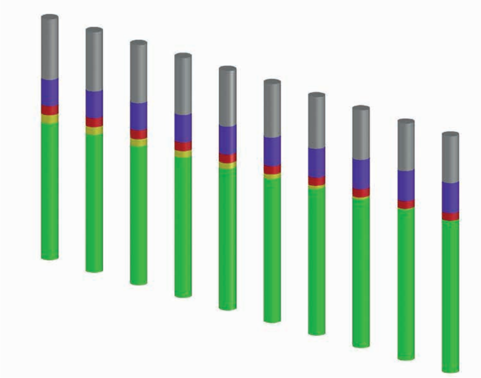


Figure 8: Drilled material arising from boreholes layer by layer

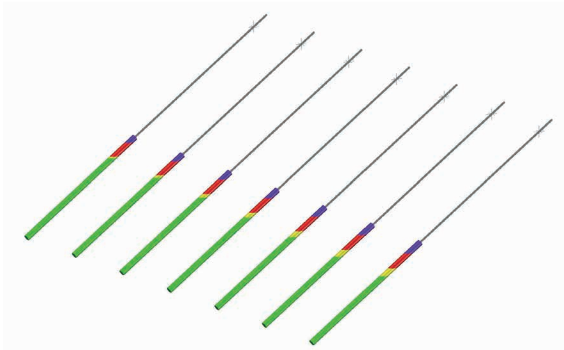


Figure 9: Optimisation of location of anchors in selected ground layers

4.3.3 Partial model of hydrology

If complex ground water conditions are encountered, then a separate hydrological model may be necessary. This should be developed and provided by a corresponding expert in hydrology.

4.4 DETAILING OF MODEL

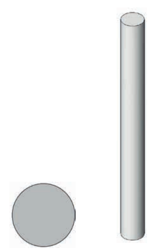
To process BIM projects, the contracting authority must specify in the Employer's Information Requirements (EIR) exactly which data are required at which points in time. The process of generating these data in the desired level of detail is described in a BIM execution plan (BEP). Who needs to pass the required information to whom by when and how this information will be passed is specified in the BEP.

In the meantime, there are a variety of abbreviations and terms defined for the level of X (LOD/LOG/LOI, etc.). However, they are not clearly defined and officially recognised or standardised. If these abbreviations are used, then it must be clarified exactly what they mean in the project.

Since there are no clear definitions for the most common abbreviations of the form "Level of X" – especially in the field of ground engineering - the general terms "level of geometry" and "level of information" are used in the following.
In general, the level of geometry and the level of information are defined for the individual objects depending on the application scenarios (AppS). In the early design phase, the levels of geometry and information are relatively low, but they become more detailed as the design phase progresses.
It is recommended to check and verify the specifications and definitions agreed to in advance based on test models.

4.4.1 Level of geometry

The level of geometry describes the type and scope as well as the level of development of the required geometric information for model elements in a specific phase. In a broader sense, this can be compared to the ever-increasing scales and the associated higher level of detail of conventional 2D design, depending on the phase of the project. The level of geometry can be divided into various stages just like the level of information. In the following examples (Fig. 10 and 11), the abbreviation LOG is used to refer to the level of geometry.

LOG	Description	Component
100	The pile is illustrated in the form of a spacer.	Axis, point, grid
200	Illustration with approximate position, length and diameter.	

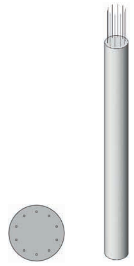
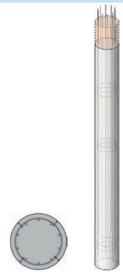
LOG	Description	Component
300	Illustration with precise position, length and diameter and precise angle of inclination. Form of pile head and toes are illustrated in an informative manner.	
400	Implementation-ready illustration based on LOG 300 with precise head and toe formation. Reinforcement shells need to be modelled. Precise illustration of reinforcement is possible as a supplementary item (LOG 450).	
500	Illustration as in LOG 400, but with as-built position, length and angle of inclination with deviation outside the defined tolerance range (‚as-built').	

Figure 10: Geometrical level of detail, taking the example of a pile

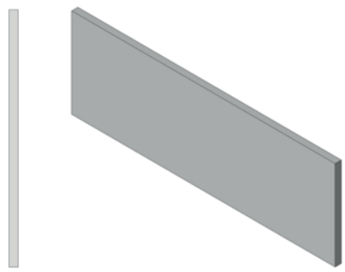
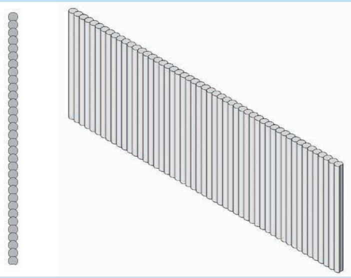
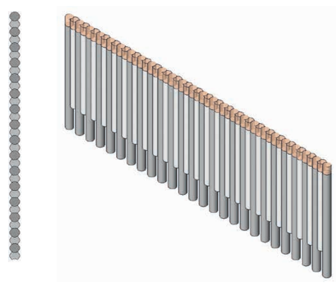
LOG	Description	Component
100	The pile wall is illustrated in the form of a spacer.	Axis, grid
200	The pile wall is illustrated in an idealized form as a wall panel with approximate position, thickness and height.	
300	The pile wall is no longer illustrated as a standalone item but instead as a group of individual piles. The requirements for individual piles are defined under ‚LOG 300 pile'.	
400	The pile wall is no longer illustrated as a standalone item but instead as a group of individual piles. The requirements for individual piles are defined under ‚LOG 400 pile'. Additional illustration of the overlap.	
500	The pile wall is no longer illustrated as a standalone item but instead as a group of individual piles. The requirements for individual piles are defined under ‚LOG 500 pile'. Additional illustration of the overlap.	

Figure 11: Geometrical level of detail, taking the example of a pile wall

Describing the requirements on the level of geometry of model elements is a relatively complex process. It generally makes sense to refer to predefined part catalogues, object catalogues, or similar reference materials. However, it will always still be necessary to adapt them accordingly to a specific project due to the special features of the corresponding construction project.
This includes determining if components or groups of components should be used (e.g. a part as manufactured as a single component or steel bracing after mounting as a component group). Furthermore, this also includes describing which components of a part should be represented separately (e.g. the anchor head of a ground anchor).

4.4.2 Level of information

The level of information describes the type and scope as well as the level of development of the required non-geometric information for model elements in a specific phase. Minimum requirements for the information content of model elements can be defined throughout the entire project and extended on a project-specific basis.

Describing the requirements for non-geometric information is much easier than describing the requirements for graphic information. It is recommended to create lists or databases for this purpose containing the required alphanumeric/product-related data for the particular classifications. The following diagram shows how the information should be organised in the model.

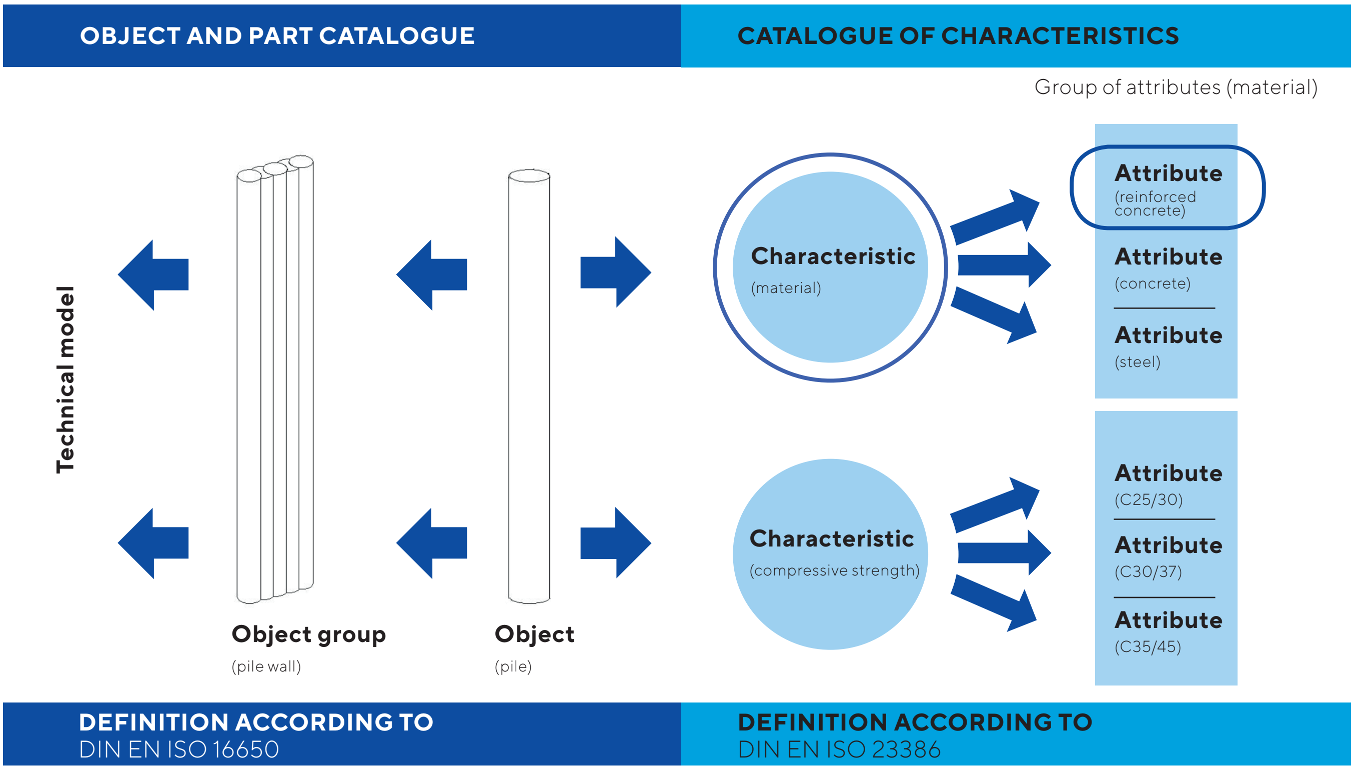


Figure 12: Overview of the assignment of part information

Different information (characteristics) and their specification(attributes) are created in a part.
Figure 12 illustrates an example of this based on a pile. The pile has the characteristic "material" and the attribute "reinforced concrete". It also has the characteristic "compressive strength" and the attribute "C35/45". This means that the part is a reinforced concrete part with the compressive strength class C35/45 is.

5 DATA EXCHANGE

5.1 CLASSIFICATION

Classification systems are used to uniquely and uniformly identify element types so that models can be evaluated in a standardised manner. This is relevant in particular to the implementation of the application scenarios 2.5 "Determination of quantities" and 2.6 "Cost planning and invitation to tender". Since elements of ground engineering are often not listed with the desired level of detail in the known classification systems such as Uniclass, a classification system for ground engineering is defined in Appendix 1. The classification system does not contradict the project structure and should instead be understood as an extension to the project structure that describes the project-specific structure of the model.

The classification system is hierarchical and is generated in the following order:
Trade → Function → Component Group → Component

The resulting code, and thus the property on the model element, is referred to as SPTB1.0 code (the abbreviation is derived from the German word for ground engineering) - see Appendix 1. It is generated from these individual levels, each of which is separated by dashes:

XX-XX-XXX-XXX

Specific combinations of these fields are not specified as a standard. To avoid language barriers, a numerical structure was chosen. The users can decide if all levels of the code as well as the resulting SPTB1.0 code itself are stored in the model element as attributes or if only the SPTB1.0 code will be used.

Example:

Attribute		**Value**	
SPTB1.0-Trade	**XX**-XX-XXX-XXX	10	(ground engineering)
SPTB1.0-Function	XX-**XX**-XXX-XXX	25	(temporary excavation pit support/retaining wall)
SPTB1.0-ComponentGroup	XX-XX-**XXX**-XXX	030	(secant bored pile wall)
SPTB1.0-Component	XX-XX-XXX-**XXX**	140	(pile)
SPTB1.0-Code		**10-25-030-140**	

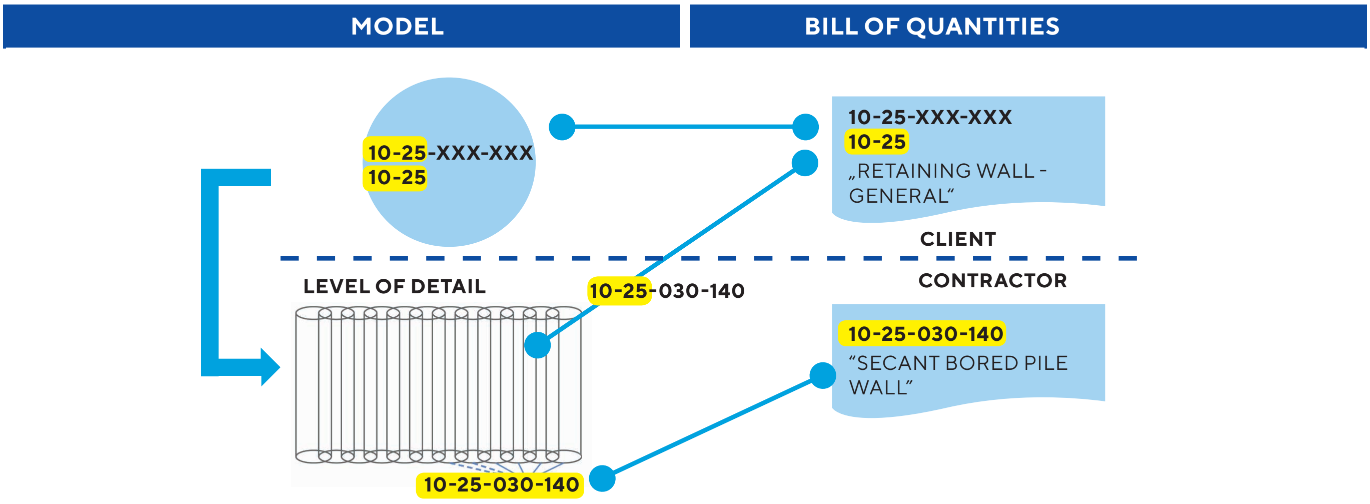


Figure 13: Example for the application of the classification system

Component types (e.g. reinforcement → pile reinforcement, panel reinforcement) are not listed explicitly in the classification system but are represented with the help of the component type property. Information on potential component types is shown in the comment column. This applies equally to the representation of existing structures, temporary/permanent and precast parts, which is why the minimum requirements for all elements includes the properties existing yes/no, temporary yes/no, and precast part yes/no.
The level of detail in the lowest level of the classification system is based on the smallest unit that can be invoiced.

5.2 FILE FORMATS

A standardised and neutral data format shall be chosen for handover of the models, ideally supplemented by the original proprietary data. In the construction industry, the data exchange format "Industry Foundation Classes" (IFC) is an example of such a format. The exchange formats and related versions of diagrams and/or programs must be discussed and agreed to by all parties involved at the start of the project and documented in the BEP together with the export settings. Ideally, the formats are verified in advance based on test models and modified accordingly if necessary.

Specific details relating to the IFC entities to be used are not provided because specific model elements tend to be used for components in ground engineering. These elements can usually only be exported from the author systems in the form of IfcBuildingElementProxy entities. We therefore refer you to the SPTB1.0 classification system described above instead.

6 ASSURANCE OF MODEL QUALITY CONTROL

6.1 ROLES AND RESPONSIBILITIES

For the implementation of BIM in projects, BIM-specific roles need to be filled. The designations are defined specifically for each project, e.g. BIM manager, BIM overall coordinator, BIM coordinator, etc. Whether or not separation of management and coordination is necessary in a project should be decided on a project-by-project basis and then stored in the EIR. In terms of assuring the model quality, the BIM manager generally defines the type and the scope of the quality assurance measures in the BIM Execution Plan. The BIM coordinator is responsible for their implementation.

6.2 QUALITY ASSURANCE MEASURES

Measures for assuring the quality of BIM models can be divided into in three different categories: geometric, functional, and content tests.

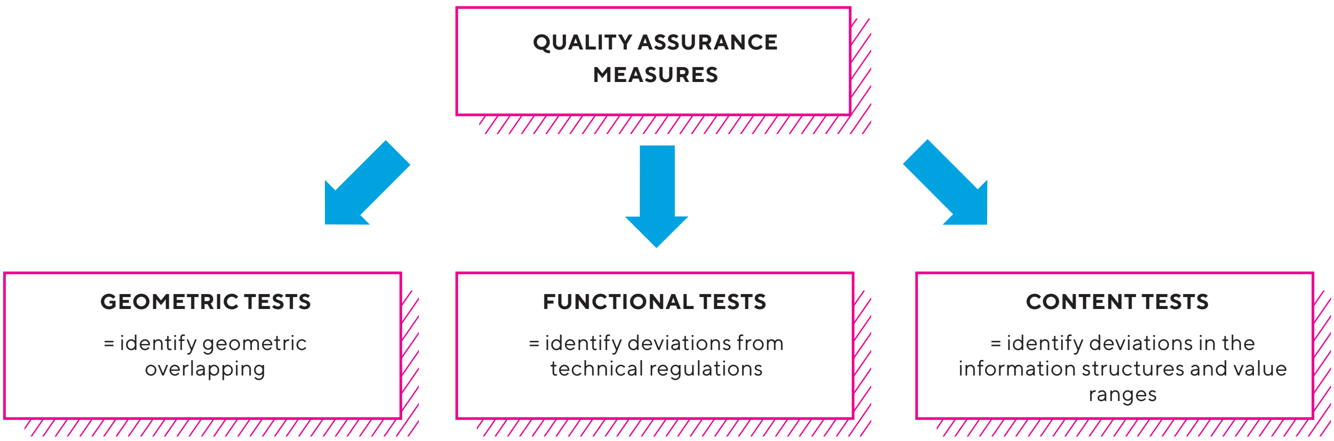


Figure 14: Quality assurance measures

Before even starting the modeling phase, the minimum requirements and test criteria for the model quality are defined in the Employer's Information Requirements (EIR). To ensure consistency among the individual models, additional requirements need to be considered by the person creating the model. The quality assurance measures should be planned at the same time the BIM Execution Plan (BEP) is created. The requirements of the application scenarios (AppS) implemented in the project form the basis for the minimum requirements and test criteria.
Quality assurance should be performed as an input check and as an output check when handing over information and/or models: Before the completed technical or partial model is handed over, the information author checks the quality of his or her work in the framework of their obligation to perform self-checks based on minimum requirements specified. Furthermore, it is necessary to ensure that each model element contained in the model has been classified based on the conditions previously agreed to.
This first level of quality assurance includes a geometric, a functional, and a content check of the particular model. Before further use of the model, the model shared using a common data environment is checked by the recipient of the information in the framework of a completeness check in terms of the content, version, nomenclature, and format. In the second level of quality assurance, the quality and consistency of the technical or partial models are checked by several model creators. The recipient of the information combines cleaned models suitable for quality assurance and coordination purposes and whose consistency has already been checked into a coordination model. The geometric, functional, and content quality assurance measures can then be performed on the consolidated model.
Conflicts determined semi-automatically are to be classified and categorised in terms of their relevance to the construction in coordination between the provider and the recipient of the information. Conflicts that have been completely classified, grouped, and categorised as collisions are shared with the model creator. They can be shared in the form of a collision report or through a common database.
In addition to the geometric test of the consolidated model, it is also possible to perform functional checks on the model. Possible functional deviations from technical and statutory regulations in a BIM model include deviations from the building regulations, regulatory compliance, construction-related specifications, and other regulations. Some tools allow semi-automatic checks of the model's compliance with building regulations. Depending on the project, functional checks can be converted to geometric checks using auxiliary structures. In this case, auxiliary objects representing empty spaces are modeled with collision geometries and then checked for geometric conflicts.
In the content check of the consolidated model, it is checked if the information is available in the right location and if the correct syntax was used. Content checks are not intended to check if the information itself is correct. They are necessary, though, to enable automation of the processes since the quality of the results of the process depend primarily on the quality of the input information.
With the previously available tools for checking building models, the geometric aspects of the model elements were not adequately checked. It must be checked manually first if the model contains the required level of detail.

7 RECOMMENDATIONS FOR THE CREATION OF EMPLOYER'S INFORMATION REQUIREMENTS (EIR)

For the successful implementation of BIM during the project and afterwards, the customer must clearly define the goals, the requirements, and the expected results. This description of the company-specific and project-specific requirements is referred to as the EIR. It must clearly answer the question of "why which information will be needed and when" for each scenario and adequately describe the expected model-based information to be delivered. In addition, it should define which standards and processes should be used to deliver the information. The technical implementation is generally initially described by the contractor in the BEP. The BEP specifies in detail how the parties will cooperate in the project based on the EIR (who will provide the required information, how will it be provided, and where will it be provided).

The requirements in the EIR should be as specific as possible and not be of a general nature. Instead, the description should be specific, suitable, and appropriate and describe in detail the requirements on the project, the construction process, and the flow of information.

The contracting authority should provide the contractor with clear specifications of the following aspects at a minimum:

- Project description (information, structure)
- Roles and responsibilities (organisation)
- BIM goals
- BIM application scenarios
- Model contents and structure
- Common data environment (CDE) and data exchange formats
- Contractual information (liability, copyrights)

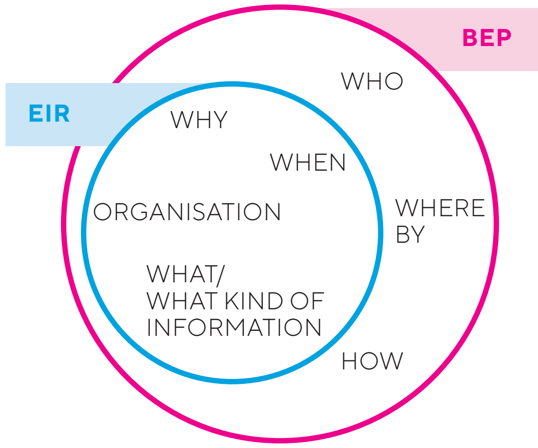


Figure 15: Interaction of EIR and BEP

8 SUMMARY

The digitalisation of the construction sector leads to massive process changes in the ground engineering sector as well as in the bidding phase and the execution phase.

Against this backdrop, the Federal Department of Ground Engineering (BFA Spezialtiefbau) in the German Construction Industry Federation initiated the working group "BIM in ground engineering" and published this position paper representing the views of ground engineering companies. The initial position paper (12/2017) was revised and expanded and is now available in a new edition (12/2019).

It begins by describing BIM application scenarios in ground engineering. A separate chapter describes the requirements on the technical model of the ground. Furthermore, data exchange scenarios (AS1 to AS4) are described and minimum requirements for the information models to be handed over are defined for each phase of the construction project. To identify elements clearly and uniquely, and therefore to enable standardised evaluations of the models, a classification system for ground engineering (SPTB1.0 Code) was defined (see Appendix 1). In Appendix 2 of this position paper, the minimum requirements for key model elements used in the ground engineering sector are specified in detail in a table.

The levels of geometry and the levels of information are described. These levels may change and go into greater depth in the different design phases. The exchange scenarios mentioned above define minimum requirements on elements typically used in ground engineering.
It also points out the essential and necessary quality controls to be performed by the model creator and the model user.

Recommendations for employer's information requirements as well as a glossary have also been added to this position paper.

This position paper summarises the viewpoint of ground engineering companies as users and as creators of digital building information models and invites readers to discuss these viewpoints.

Due to the dynamic development of the subject of BIM, this position paper is not conclusive and is subject to further revision.

9 GLOSSARY

3D model A simplified, three-dimensional, digital representation of a structure/an actual situation

4D model An expanded 3D model in which the model elements are assigned to tasks in a schedule

5D model A model in which the times and costs are linked to the objects of the 3D model

As-built model A structural design model created during project execution that reflects the current state down to the level of detail selected.

Attribute A characteristic of each feature, e. g. C25/30, C30/37.

Application scenario (AppS) Describes a BIM task to be implemented a BIM project.

BIM – Building Information Modeling A work method in which the spatial structure of the components in a digital building information model is documented, whereby components of the structural and technical systems are described by their characteristic properties and by their relationships with each other.
A method for the design, execution, and operation of buildings in a collaborative manner based on the central provision of information for shared use.
BIM is not a software package, but a work method that facilitates project management as well as cooperation in all phases of the life cycle of a structure.

BIM Execution Plan - BEP A document that describes the basis of BIM-based cooperation in a project. It specifies the corresponding responsibilities. It also represents the framework for the BIM services (who, with what, how) and defines the processes as well as exchange requirements for each of the parties involved. The BEP should be a part of the contract made between the client and those involved in the project.

BIM coordination/BIM coordinator BIM coordination is a project role for the technical or task-specific implementation of the contents agreed to in the BEP.
BIM coordinators are the people responsible for this.
The tasks of the BIM coordination comprise the following in particular:
• The technical or task-specific coordination and checking the quality of the models while they are being created
• The technical or task-specific implementation of the BIM execution plan

• Involvement in the creation and further development of the BIM execution plan
• Exchange information with the BIM management
• Exchange data within the specialised discipline
(Source: own definition)

BIM management/BIM manager The BIM management is the main role for strategic project management of the contents agreed to in the BEP.
BIM managers are the people responsible for this.
The project management role comprises the main tasks for which the BIM management is responsible, in particular:
• Exchange of information with customers and others involved in the project
• Creation, implementation, further development of the BIM execution plan
• Administration of the common data environment
• Agreement on and implementation of the flow of information into the model and out of the model
• Overall coordination of the model-based collaboration
Note: Some customers use other names for the same position or role to emphasise the hierarchies.
(Source: adapted from PAS 1192-3 and CIC "Outline Scope of Services for the Role of Information Management")

Catalogue/part catalogue A systematically ordered list of components and their properties that can be used to enrich building information models in a consistent manner.

Characteristic Non-geometric, semantic information for a component, e. g. the concrete strength class

Classification system A numeric or alphanumeric code used to identify element types clearly and uniquely

Data exchange scenario (DES) A process carried out at a defined time at which data is exchanged among those involved. A data exchange scenario can contain one or more exchange requirements.

Digital Terrain Model (DTM)/Digital Surface Model (DSM) Elevations of the surface with or without vegetation

EIR – Employer's Information Requirements A document in which the customer describes the relevant goals and applications as well as the services and data the contractor must supply. It specifies in particular the specific times, methods of provision, levels of detail, data structures, and data formats to be used to deliver the data.

Entity A class of information that is defined by common attributes and restrictions

Ground layer model (GLM) A digital implementation of the geotechnical report; it is the responsibility of the geotechnical expert.

Ground model (GM) All information that describes the ground as well as the terrain. This includes geometric data such as the elevations of the surface of the terrain and depths of layers as well as soil characteristics of the ground based on the geotechnical report.

IFC (Industry Foundation Class) A cross-manufacturer and cross-national interface for model-based data and information exchanges

Point cloud A set of points that describe a three-dimensional space, whereby the points contain additional information such as intensity or colour values in addition to their coordinates (X, Y, Z)

10 APPENDICES

Appendix 1 Classification system
Appendix 2 Minimum requirements for model elements

11 SOURCES, PHOTO ACKNOWLEDGEMENTS, LINKS

Title image	Example illustration of excavation design, Züblin
Figure 1:	Requirements for the modeling depth and the characteristics of object properties based on BIM application scenarios; Implenia
Figure 2:	Application scenarios in ground engineering; Position Paper "BIM im Hochbau" (German only); Images/contents adapted accordingly
Figure 3:	Example of coordination of ground engineering trades; Züblin
Figure 4:	Model structure; Wayss & Freytag
Figure 5:	Technical models and coordination model; Implenia/Züblin
Figure 6:	Types of point networks (a) Grid (b) TIN (c) Vector-based model; Wilson & Gallant, 2000
Figure 7:	Example of an excavation pit coordination model with a ground layer model; Züblin
Figure 8:	Drilled material (layer by layer); Züblin
Figure 9:	Optimisation of the location of anchors in selected ground layers; Züblin
Figure 10:	Level of geometry based on an example of a pile; Züblin
Figure 11:	Level of geometry based on an example of a pile wall; Züblin
Figure 12:	Overview of component information assignments; Implenia
Figure 13:	Example of the application of the classification system; Implenia
Figure 14:	Measures for quality assurance; position paper "BIM im Hochbau" (German only)
Figure 15:	Interaction of the EIR and BEP; Züblin

SOURCES:

„BIM im Hochbau - Technisches Positionspapier"
(BIM in Structural Engineering - Technical Position Paper)
"Structural Engineering" working group in the "Digital Construction" working committee of the German Construction Industry Federation (publisher), 2019

"BIM in Tunnelling - Digital Design, Building and Operation of Underground Structures",
German Tunnelling Committee (DAUB) (publisher), 2019

"BIM4INFRA 2020 Handreichungen und Leitfäden - Teil 6: Steckbriefe der wichtigsten BIM-Anwendungsfälle"
(BIM4INFRA 2020 Handouts and Guides - Part 6: Profile of the most important BIM application scenarios)
Federal Ministry of Transport and Digital Infrastructure (publisher), 2015.

LINKS:

Link 1 **Stepwise plan for digital construction (German only)**
https://www.bmvi.de/SharedDocs/DE/Publikationen/DG/stufenplan-digitales-bauen.pdf?__blob=publicationFile

Link 2 **BIM Guide for Germany:**
https://www.bbsr.bund.de/BBSR/DE/FP/ZB/Auftragsforschung/3Rahmenbedingungen/2013/BIMLeitfaden/Endbericht.pdf?__blob=publicationFile&v=2

Link 3 **ARGE BIM4INFRA2020**
https://bim4infra.de/

Link 4 **BIM in Tunnelling:**
http://www.daub-ita.de/fileadmin/documents/daub/gtcrec4/gtcrec11v3_BIM_im_Untertagebau_05-2019.pdf

12 LIMITATION OF LIABILITY, COPYRIGHT/ ANCILLARY COPYRIGHT

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POSITION PAPER “BIM IN GROUND ENGINEERING”
APPENDIX 1 - CLASSIFICATION SYSTEM
(AS OF: DECEMBER 2019)

IMPORTANT NOTE:
The classification system is structured hierarchically in the following sequence: Construction sector > Function > Component group > Component

Example: STPB1.0-Code: 10-50-070-140

CONSTRUCTION SECTOR

XX	Information not known/ not assigned
10	Ground engineering
20	Earth works
30	Geothermics
40	Structural engineering
50	Dewatering

FUNCTION

XX	Information not known/ not assigned
10	Uplift restraint
15	Sealing
20	Temporary construction
25	Retaining wall
30	Preservation of structures
35	Ground improvement
40	Slope stabilization
45	Investigation
50	Foundation
55	Explosive ordnance detection
60	Monitoring
65	Supporting structure (permanent)
70	Underpinning

COMPONENT GROUP

XXX	Information not known/ not assigned
010	Bracing
015	D-wall barrette foundation
020	Contiguous bored pile wall
025	Tangential bored pile wall
030	Secant bored pile wall
035	Sealing shield
040	Sealing slab
045	Slurry wall
050	Dynamic compaction
055	Shallow foundation
060	Grouting
065	Nail wall
070	Pile foundation
075	Anchorage
080	Vibro stone columns
085	Diaphragm wall
090	Probing
095	Sheet pile wall
100	Soldier pile wall
105	Freezing

COMPONENT

XXX	Information not known/ not assigned
010	Anchor
015	Anchor head support
020	Eembankment
025	Infilling
030	Excavation
035	Concrete slab
040	Reinforcement
045	Soil body
050	Ground improvement column
055	Drilling template
060	Bore
065	Wells
070	Insulation
075	Sealing structure
080	Sealing element
085	Waling
090	Backfill
095	Grouting element
100	Bracket
105	Anchor head detail
110	Top supporting beam
115	Panel
120	Guide wall
125	Monitoring
130	Nail
135	Level
140	Pile
145	Shotcrete
150	Sheet pile
155	Strut
160	Tolerance element
165	Girder
170	Freezing element
175	Tie rod

THE FOLLOWING EXAMPLES SHOULD SERVE TO ILLUSTRATE THE SYSTEM:

CONSTRUCTION SECTOR	FUNCTION	COMPONENT GROUP	COMPONENT	SPTB1.0-CODE
GROUND ENGINEERING	FOUNDATION	PILE FOUNDATION	PILE	
10	50	070	140	10-50-070-140
GROUND ENGINEERING	EXCAVATION PIT SUPPORT	ANCHORAGE	ANCHOR	
10	25	075	010	10-25-075-010

POSITION PAPER “BIM IN GROUND ENGINEERING”
APPENDIX 2 - MINIMUM REQUIREMENTS FOR MODEL ELEMENTS (AS OF: DECEMBER 2019)

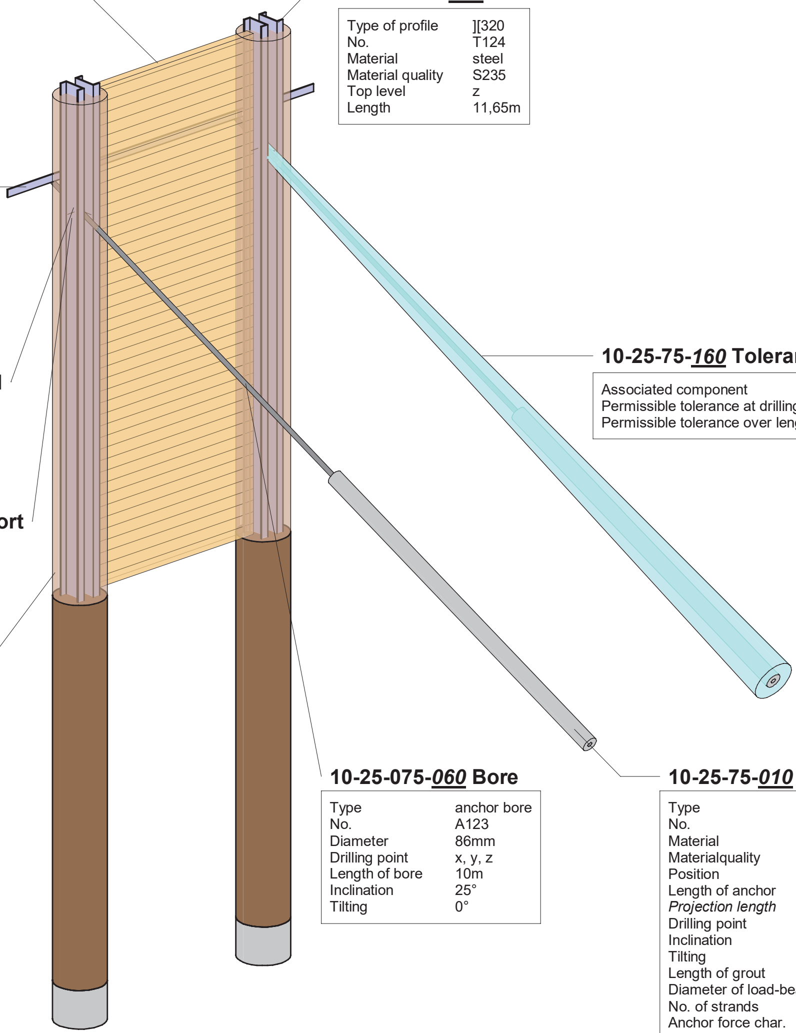
IMPORTANT NOTE:
All of the various partial models and model elements must at least feature the properties in this list. The properties marked with an „x“ in the following table must contain corresponding information.
Further properties or technical requirements relevant to project execution can be added.
Regardless of the minimum requirements listed below the applicable current standards and regulations must be observed.
The mentioned minimum requirements apply to components which are shown as single objects in the model.

The data exchange scenarios AS1 - AS4 refer to the description in Chapter 3 of the main document. The following exchange scenarios are defined:

AS1 - Invitation to tender
AS2 - Detailed design
AS3 - Planning of works
AS4 - Existing structural model („as-built“)

IMPORTANT NOTE:
- The characteristic „amount of reinforcement“ is not applicable if type/material is not „reinforced concrete“
- If the characteristic „amount of reinforcement“ is available, the characteristic „type of reinforcement“ (e.g. steel fiber, GRP, etc.) must also be available.

Explanatory example: Soldier pile wall 10-25-100-xx with anchors 10-25-075-xx



10-25-100-*025* Infilling

Type	timber
No.	-
Material	timber
Material quality	C24
Top level	z1
Bottom level	z2
Thickness	12cm
Distance of girders	2,50m

10-25-100-*165* Girder

Type of profile	][320
No.	T124
Material	steel
Material quality	S235
Top level	z
Length	11,65m

10-25-100-*175* Tie rod

Type	flat steel
Material	steel
Material quality	S235
Height position	location of anchor 1
Length	[lable length building]
Width	100mm
Thickness	10mm

10-25-75-*160* Tolerance element

Associated component	anchor / 10-25-75-010
Permissible tolerance at drilling point	5cm
Permissible tolerance over length	2%

10-25-075-*105* Anchor head detail

Type	strand anchor, strain
No.	A123
Material	according to approval
Materialquality	according to approval

10-25-075-*015* Anchor head support

Type	lowered, temporary
No.	A123

10-25-100-*060* Bore

Type	girder bore
No.	B123
Diameter	0,66m
Drilling point	x, y, z
Length of bore	12m
Inclination	-
<u>Drill hole</u>	
Length	6,50m
Material	sand
Material quality	???
<u>Clamping range</u>	
Length	5,00m
Material	hydraulically bonded material
Material quality	???
<u>Seal</u>	
Length	50cm
Material	in-situ concrete
Material quality	C16/20, X0

10-25-075-*060* Bore

Type	anchor bore
No.	A123
Diameter	86mm
Drilling point	x, y, z
Length of bore	10m
Inclination	25°
Tilting	0°

10-25-75-*010* Anchor

Type	strand anchor
No.	A123
Material	strand steel
Materialquality	St1570/1770
Position	1
Length of anchor	10m
Projection length	*60cm*
Drilling point	x, y, z
Inclination	25°
Tilting	0°
Length of grout	5m
Diameter of load-bearing element	0,60"
No. of strands	3
Anchor force char.	163kN
Lock-off force	163kN
Test load	245kN
Working platform	[z - 50cm]

COMPONENT CODE	COMPONENT / CHARACTERISTICS	UNIT	EXCHANGE SCENARIOS AS1	AS2	AS3	AS4	COMMENT/REFERENCE
010	**Anchor**						
	Type	-		x	x	x	Permanent or temporary anchor / Strand or single-rod anchor
	Number	-		x	x	x	
	Material	-		x	x		
	Material quality	-		x	x		e.g. 1570/1770
	Anchor position	-		x	x	x	e.g. A, B, C / 1, 2, 3 etc.
	Anchor location	-		x	x	x	coordinates x, y, z with reference to the axis
	Working level	müNN	x	x	x		
	Anchor reference length	m	x	x	x	x	from rear edge of VP body to middle of retaining wall
	Length of compression element	m	x	x	x	x	
	Vertical inclination	-	x	x	x	x	top/bottom, with reference to the horizon
	Horizontal inclination (building axis)	-		x	x	x	clockwise/anti-clockwise direction of rotation
	Diameter of load-bearing element	mm		x	x	x	
	Number of strands/rods	St		x	x	x	e.g. 4 strands
	Diameter of single load-bearing element	mm		x	x		Ø 0,6″
	Anchor force	kN	x	x	x		
	Lock-off force	kN		x	x		possibly lock-off factor
	Test load	kN			x		
015	**Anchor head support**						
	Type	-		x	x	x	countersunk/top-mounted; temporary/permanent
	Number	-		x	x	x	
020	**Embankment**						
	Type of soil	-		x	x	x	e.g. SU, SW, GU...
	Degree of compression	-	x	x	x	x	
	Volume	m^3	x	x	x	x	
025	**Infilling**						
	Type	-		x	x	x	e.g. timber, shotcrete, precast element, sheet piles...
	Number	-		x	x	x	
	Material (to be indicated separately for all components)	-	x	x	x		e.g. concrete, timber
	Material quality (to be indicated separately for all materials)	-		x	x	x	e.g. C25/30 XC2 XA1
	Top level	müNN	x	x	x	x	
	Bottom level	müNN	x	x	x	x	
	Thickness	cm	x	x	x		
	Centre-to-centre distance of girders	m	x	x	x		
	Reinforcement content	kg/m^3		x	x		
030	**Excavation**						
	Volume	m^3	x	x	x	x	
	Feature definition according to DGGT Working Group Digitilization in Geotechnics (in progress)						
035	**Concrete slab**						
	Type	-	x	x	x	x	UW concrete base, clean layer, surface foundation...
	Material (to be indicated separately for all components)	-	x	x	x		e.g. concrete, steel
	Material quality (to be indicated separately für all materials)	-	x	x	x		e.g. C25/30 XC2 XA1
	Top level	müNN	x	x	x	x	
	Thickness	m	x	x	x		
	Volume	m^3	x	x	x	x	
	Reinforcement content	kg/m^3	x	x	x		
040	**Reinforcement**						
	Type	-		x	x	x	e.g. cage/ rebars, mesh, fibres
	Number	-		x	x	x	for pile or D-wall reinforcement
	Material	-		x	x		e.g. steel, glass fibre
	Material quality	-	x	x	x		e.g. BSt500S
	Quantity	to		x	x		
045	**Soil body**						
	Feature definition according to DGGT Working Group Digitilization in Geotechnics (in progress)						
050	**Ground improvement column**						
	Type	-	x	x	x	x	e.g. vibro stone columns, CSV, vibro compaction
	Number	-		x	x	x	
	Material	-	x	x	x	x	
	Material quality	-		x	x	x	
	Top level	müNN	x	x	x	x	
	Bottom level	müNN	x	x	x	x	
	Diameter	cm	x	x	x	x	
	Working level	müNN	x	x	x		
055	**Drilling template**						
	Material (to be indicated separately for all components)	-		x	x		e.g. concrete
	Material quality (to be indicated separately für all materials)	-		x	x		e.g. C25/30
	Top level	müNN			x		
	Thickness	m			x		
	Width	m			x		
	Length	m	x	x	x		measured in pile wall axis
	Centre-to-centre distance of bores	m		x	x		
	Opening diameter	mm		x	x		
	Reinforcement content	kg/m^3		x	x		

COMPONENT CODE	COMPONENT / CHARACTERISTICS	UNIT	EXCHANGE SCENARIOS				COMMENT/REFERENCE
			AS1	AS2	AS3	AS4	
060	**Bore**						
	Type	-		x	x	x	e.g. investigation, exchange bore, bore (decompaction bore), anchor bore, pile bore
	Number	-		x	x		
	Material (to be indicated separately for all components)	-		x	x	x	e.g. backfilling material SE
	Material quality (to be indicated separately for all materials)	-	x	x	x	x	e.g. 8/16
	Diameter	mm	x	x	x	x	
	Drilling location	-			x		coordinates x, y, z with reference to the axis
	Length of bore	m	x	x	x		
	Horizontal inclination	degree	x	x	x	x	
	Vertical inclination	degree	x	x	x	x	
	Direction of inclination	-		x	x	x	with unique reference (e.g. axis of building, lining axis, North azimuth)
	Length of backfilling (to be indicated separately for all materials)	m	x	x	x	x	
065	**Wells**						
	Type	-		x	x	x	e.g. filter wells
	Number	-		x	x		
	Bottum level of well pipe	müNN		x	x	x	
070	**Insulation**						
	Material (to be indicated separately für all components)	-		x	x		
	Material quality (to be indicated separately for all materials)	W/(m²K)	x	x	x		Heat transfer coefficient U
	Length	m	x	x	x		
	Width	m	x	x	x		
075	**Sealing structure**						
	Type	-		x	x	x	e.g. jet grouting column, sealing wall
	Material (to be indicated separately für all components)	-		x	x	x	
	Material quality (to be indicated separately for all materials)	-	x	x	x	x	
	Volume	m³	x	x	x	x	
080	**Sealing element**						
	Type	-		x	x		e.g. joint tape, panel seal
	Material	-		x	x	x	e.g. Elastomer, steel
	Material quality	-	x	x	x	x	
	Length	m	x	x	x	x	
085	**Waling**						
	Material (to be indicated separately for all components)	-					e.g. concrete, steel
	Material quality (to be indicated separately for all materials)	-	x	x	x		
	Height position	müNN		x	x		
	Length	m	x	x	x		
	Profile			x	x		e.g. double U 300/200mm (steel), 60/40cm (concrete)
	Reinforcement content	kg/m³		x	x		
090	**Backfill**						
	Material (to be indicated separately for all components)	-	x	x	x	x	
	Material quality (to be indicated separately für all materials)	-		x	x	x	e.g. bulk materials GW, GI
	Degree of compression Ev2	to/m³		x	x	x	alternatively Dpr [%]
	Volume	m³	x	x	x	x	
095	**Grouting element**						
	Type	-	x	x	x		e.g. grouting slab
	Material	-	x	x	x	x	
	Material quality	-		x	x	x	
	Volume	m³		x	x	x	
100	**Bracket**						
	Type	-	x	x	x		
	Number	-	x	x	x	x	
	Material (to be indicated separately für all components)	-		x	x	x	
	Material quality (to be indicated separately for all materials)	m	x	x	x	x	
		kg/m³		x	x		
105	**Anchor head detail (element of another component, e.g. micro pile pressure / tension, anchor, rigidity etc.)**						
	Type	-		x	x	x	e.g. micro pile pressure / tension, anchor, rigidity
	Number	-		x	x	x	
	Material (to be indicated separately für all components)	-		x	x	x	
	Material quality (to be indicated separately for all materials)	-		x	x		
110	**Top supporting beam**						
	Material	-	x	x	x	x	e.g. concrete
	Material quality	-		x	x	x	e.g.. C25/30
	Top level	müNN	x	x	x	x	
	Length	m	x	x	x	x	
	Width	m	x	x	x	x	
	Height	m	x	x	x	x	
	Reinforcement content	kg/m³	x	x	x	x	

COMPONENT CODE	COMPONENT / CHARACTERISTICS	UNIT	EXCHANGE SCENARIOS				COMMENT/REFERENCE
			AS1	AS2	AS3	AS4	
115	**Panel**						
	Type	-	x	x	x	x	e.g. SW / DW / 1 or 2 phase wall
	Number			x	x	x	panel
	Material (to be indicated separately für all compo-nents)	-	x	x	x	x	Process-related materials are usually determined by the company carrying out the work
	Material quality (to be indicated separately for all materials)	-		x	x	x	e.g. minimum density suspension in kg/m³
	Thickness	m	x	x	x	x	
	Top level	müNN	x	x	x	x	top level panel
	Height	m	x	x	x	x	from top level of panel to bottom level
	Length	m		x	x		
	Panel drawing	-			x		incl. quantity and number
	Working platform	müNN	x	x	x		
	Backfilling of empty panel	m³		x	x	x	
	Suspension surface level	müNN		x	x		
	Type of panel	-			x		starter, intermediate, closure, kink panel
	Type of joint	-			x		flat joint / stop-end joint / pre-cast joint
	Installation parts	-	x	x	x	x	e.g. Inclinometer; anchor pots; anchor plates etc.
120	**Guide wall**						
	Type	-					one-sided/two-sided
	Material (to be indicated separately for all components)	-		x	x		
	Material quality (to be indicated separately for all materials)	-		x	x		
	Top level	müNN			x		
	Length (measured in sector angle axis)	m	x	x	x		
	Width	m			x		
	Height	m					
	Offset to outer edge of diaphragm wall	m			x		planned interval and manufacturing tolerance
	Reinforcement content	kg/m³		x	x		
125	**Monitoring**						
	Type	-		x	x	x	e.g. temperature, deformation; Inclinometer, Extensometer, ...
	Number	-		x	x	x	
130	**Nail**						
	Type	-	x	x	x	x	z. B. temporarily, permanent, GEWI, self-drilling systems
	Number	-		x	x	x	
	Material (to be indicated separately for all components)	-	x	x	x	x	
	Material quality (to be indicated separately for all materials)	-		x	x	x	e.g. load-bearing element, cement
	Diameter	cm	x	x	x	x	
	Nail head leyer	-	x	x	x	x	static element, coordinates x, y, z with reference to the axis
	Length	m	x	x	x	x	
	Vertical inclination	degree	x	x	x	x	
	Direction of inclination	-		x	x	x	with unique reference (e.g. axis of building, lining axis, North azimuth)
135	**Level**						
	Type	-		x	x	x	e.g. measuring level, withdrawal level
	Number	-		x	x	x	
	Bottom level level pipe	-		x	x	x	
140	**Pile**						
	Type	-	x	x	x	x	e.g. bored pile, prefabricated pile, ductile pile , micro pile
	Number	-		x	x	x	
	Material (to be indicated separately for all components)	-	x	x	x	x	
	Material quality (to be indicated separately for all materials)	-		x	x	x	
	Diameter	mm/cm	x	x	x	x	
	Position of pile head	-	x	x	x	x	static element, x y, z
	Length	m	x	x	x	x	
	Vertical inclination	degree	x	x	x	x	
	Direction of inclination	-		x	x	x	with unique reference (e.g. axis of building, lining axis, North azimuth)
	Reinforcement content	kg/m³		x	x		
145	**Shotcrete**						
	Type	-	x	x	x	x	lagging, nailing, embankment protection
	Material (to be indicated separately for all components)	-	x	x	x	x	
	Material quality (to be indicated separately for all materials)	-		x	x	x	
	Length	m	x	x	x		
	Width	m	x	x	x		
	Depth	m	x	x	x		
	Reinforcement content	kg/m²	x	x	x		
	Single/double layer	-			x		
	Drainage apertures/drainage mats	-	x	x	x	x	grid
150	**Sheet pile**						
	Type	-	x	x	x	x	waler, pile
	Number	-		x	x	x	
	Material	-	x	x	x	x	
	Material quality	-		x	x	x	
	Top level	müNN	x	x	x	x	
	Length	m	x	x	x	x	
	Profile	-	x	x	x	x	
	Delivery form	-	x	x	x	x	single, double or triple sheet piles
	Quantity	to	x	x	x		

COMPONENT CODE	COMPONENT / CHARACTERISTICS	UNIT	EXCHANGE SCENARIOS				COMMENT/REFERENCE
			AS1	AS2	AS3	AS4	
155	**Strut**						
	Type	-	x	x	x		
	Number	-		x	x		
	Material	-		x	x		concrete, steel
	Material quality	-	x	x	x		
	Profile	-		x	x		e.g. DN 300/20mm (steel), 60/40cm (concrete)
	Height position	müNN		x	x		
	Length	m	x	x	x		
	Reinforcement content	kg/m²	x	x	x		
160	**Tolerance element**						
	associated component	-		x	x		e.g. anchor, panel, pile
	permissible tolerance in starting point	cm		x	x		
	permissible tolerance over length/depth	%		x	x		
165	**Girder (vertical)**						
	Type	-	x	x	x	x	
	Number	-.		x	x		
	Material	-		x	x		
	Material quality	-	x	x	x		
	Top level	müNN	x	x	x	x	
	Length	m	x	x	x	x	
170	**Freezing element**						
	Type	-	x	x	x		nitrogen, brine
	Material	-	x	x			frozen soil and water
	Material quality	-	x	x	x		
	Geometric dimensions	-	x	x	x		record bores, temperature measuring lances separately
	Technical requirements	-	x	x			strength, permeability, average temperature in the freezing body
	Holding period	d	x	x	x		
	Freezing time	d	x	x	x		
175	**Tie rod**						
	Type	-	x	x	x		flat steel, U profile
	Material	-	x	x	x		
	Material quality	-	x	x	x		
	Height position	müNN	x	x	x		
	Length	m	x	x	x		
	Width	mm		x	x		
	Thickness	mm		x	x		

edited by:

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