Tunnel Euralpin Lyon-Turin CO08 – BIM implementation in conventional tunneling

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ABSTRACT: In conventional tunnelling, geology and excavation behaviour allow to define the most appropriate excavation method and support sections needed during the construction phases. Because of the uncertainties on the real on-site geological conditions and soil behaviour, the design and project execution stages demand flexible organization and tools. The rapid rise of Building Information Modelling (BIM) represents a major opportunity for tunnel engineering, construction industry and public organizations to improve quality and efficiency of all services. Given the size of the project, its heterogeneity, strategic role, and sustainability, TELT puts forward the fully BIM approach to ensure the efficiency of the design, organization of information flows.

This paper focuses on the BIM application on the construction site 8 (CO08) of the Tunnel Euralpin Lyon Turin (TELT) project. The project is implemented by the Contractors' JV IMPLENIA FRANCE / NGE GC / ITINERA / RIZZANI De ECCHER and the design JV PINI France and Systra-SWS. The DAUB recommendation for BIM in tunnelling is applied. A database is created for all the structures and part of the structures of the project (supporting structures of the tunnel portal, conventional tunnel primary support, pre-support and final lining). All the components are fully modelled in BIM, according to the TELT technical specifications and requirements. A 3D geological model has also been implemented in order to have a dynamic comprehension of the geological sequence in all part of the tunnel alignment, to characterize the geological/geotechnical conditions and uncertainties at the tunnel face during construction, and to allow the Contractor to adapt its methods and support section.

Dynamic 4D and 5D models are developed. This will permit the Contractors to efficiently follow and adapt the construction works and methods on site.

1 GENERAL OVERVIEW OF THE PROJECT

The cross-border section of the new Lyon-Turin line is a new railway line of approximately 67 km linking Saint-Jean-de-Maurienne to Susa in Italy and Bussoleno where it connects to the historic Turin-Modane line. In particular, the line requires the boring of 57.5 km one-track twin-tunnels, known as the "Montcenis base tunnel", and of a 2 km twin-tunnel between Susa and Bussoleno, known as the "Interconnection tunnel".

On the French side, the civil engineering of the base tunnel is divided into 4 Operational Worksites ("Chantier Opérationnel" in french) ; CO08 is the one including the Villard Clément portal attacks and about 3 km long base tunnel.

The works of CO08 include the transfer of the existing structures (cut-and-cover, platform for site installations and other structures carried out as part of the preliminary works of CO09a) and the construction of all the structures of the future base tunnel over a length of approximately 1.8 to 3.8 km for each tube (including the communication cross passages, the niches and the installation of external conveyor bands for the evacuation of materials), as well as a 150 m long cut-and-cover, backfilling and definitive surface installations. For these CO08 structures, the work includes pre-support, excavation, support, waterproofing, final lining, and facilities.

One of the main challenges encountered in the project is the variability of the geotechnical conditions encountered along the tunnel alignment, with transitions between soft soils and rock and consequently the definition of numerous support profiles.

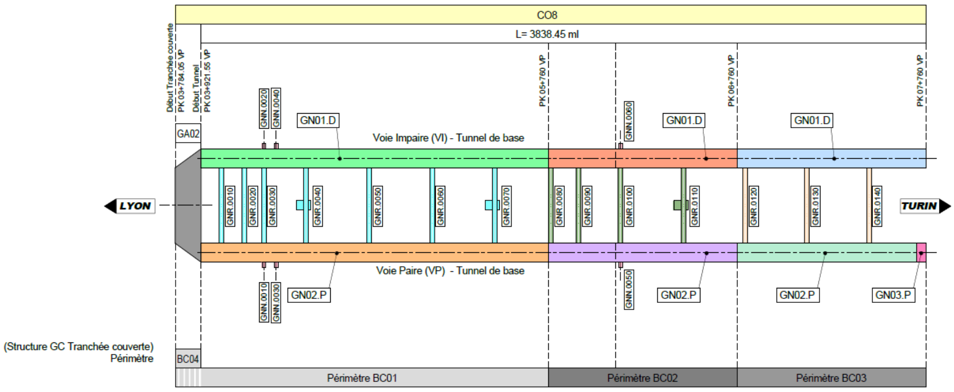

Figure 1. CO08 - Project synoptic.

2 DIGITALIZATION GOALS AND ORGANIZATION

2.1 *Digitalization goals*

TELT has decided to implement the BIM model of the new Turin-Lyon railway line, providing guidelines on the main documental and technical properties on which the model is based and has chosen to require the production of BIM models in the construction phase. The BIM approach is part of an objective to plan, facilitate construction and monitor its progress, and will have to be continued at the end of the civil engineering works to constitute the future database and the digital twin of the built structure. TELT will use this data to integrate it into its future computer-aided maintenance management system and various operational support tools. TELT has identified the following macro-objectives to ensure the goals:

- Design optimization, multidimensional modelling between disciplines and conflict detection,
- Project management, construction scheduling, sequencing (4D) and cost estimation (5D),
- Use BIM models to extract quantities for the bill of quantities,
- Facility Management for future maintenance and operation phases with BIM support,
- Public communication (videos, augmented reality, and virtual reality headsets).

In this perspective TELT, given the size of his project, its complexity, and its timeframe, can place the BIM approach among its action guidelines as an element potentially able to grant success in information flows management.

2.2 *BIM Execution Plan*

The client’s BIM specifications or requirement specification are used to control the success of the BIM-designed project. The BIM execution plan (BEP) consider the client’s BIM specifications and provides the binding agreement of a route to achieve the project requirements. The BEP is created and collaboratively further developed by the Contractor, the designers JV, and the Client. Concerning the modelling, the following main points are regulated:

- Model structure (detail and master federated BIM models),

- Coordinate origin according to LTF2004c,
- Use of alignment as reference element,
- Construction elements and their attributes,
- Unique identification codes for the construction element, according to TELT WBS,
- Color scheme.

2.3 *Digital project workflow and organization*

One elementary aspect of the BIM methodology is the central provision and administration of information as a single source of information. Therefore, the use of a common data environment CDE in the project is necessary. The collaborative platform “Kairnial” has been chosen for the CO08 project. The client is also equipped with an Autodesk ® platform in use for all operational worksites in order to group together all the models that will be produced.

3 BIM APPROACH

3.1 *BIM Model Segregation*

BIM model segmentation is a practical approach to assemble overall models out of part models to save IT resources. The models have been segmented into three main disciplines:
- Geology and geotechnics,
- Portal area,
- Soil improvement,
- Excavation and support of the main tunnels,
- Final lining and facilities of the main tunnels,
- Excavation and support of the cross passages,
- Final lining and facilities of the cross passages.

The models are arranged to be compatible with each other with the same geometrical basis.

3.2 *Tunneling BIM approach*

3.2.1 *Details and federated models*

Tunnels and cross-passages have been modelled based on the recommendation of DAUB (2019). Two different models are implemented:
- Detail model: individual tunneling classes are modeled in detail with a LoD400 and with all the attributes information. Detail models allows the extraction of detail drawings of tunneling classes,
- Master federated model: geo-referenced, the model shows the distribution of the tunnelling classes along the alignment modelled with a LoD200. This model is used for 4D and 5D uses (including quantity extraction).

3.2.2 *Parametric modelling of the tunnel and information in BIM models*

Smart definition of attribute tables for all element types is crucial. A parametric modelling system has been created by TELT combining the WBS (Work Breakdown Structure) with the PBS (Product Breakdown Structure). This identifies and distributes, in a set of coordinated, organized and hierarchical entities, all the components of the project. It is the reference key for all project stakeholders. This codification enables all the elements (objects) and information in the models to be identified in a unique and unambiguous way.

3.2.3 *Automated modelling and Dynamo*

The BIM modelling was carried out using Dynamo, which allowed the automatic and precise creation of the various objects constituting the support profiles. Moreover, the use of Dynamo and Di-Roots allowed to introduce extensively the different sets of parameters of each object in coherence with the planned codification or to update it according to the project evolution.

Maquette											Bibliothèque										
Localisation (Code WBS à titre d'exemple)											Code BIM (Famille)										
1	2	3	4	5	6	7	7b	8	9	OM	10	11	12	13	14	IDENTIFIANT	NIVEAU 10 SPÉCIALITÉ PRINCIPAL (PÉRIMÈTRE 1)	NIVEAU 11 SUB SPÉCIALITÉ (PÉRIMÈTRE 2)	NIEVAU 12 FONCTION (PÉRIMÈTRE 3)	NIVEAU 13 TYPE D'ÉLEMENT D'OUVRAGE / ÉQUIPEMENT	NIVEAU 14 MATERIAUX / COMPOSANT
STTL	T	C	F	C	000											...					
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STTL	T	C	F	C	000	GN	00	P	0	0000	GC	TF	040	020	020	GC.TF.040.020.020	GÉNIE CIVIL	Tunnel foré	Revetement	Beton_remplissage	Provisoir C30_35
STTL	T	C	F	C	000	GN	00	P	0	0000	GC	TF	040	020	030	GC.TF.040.020.030	GÉNIE CIVIL	Tunnel foré	Revetement	Beton_remplissage	Bouclier_01 C30_35

Figure 2. Example of the definition of the attributes for BIM elements.

4 GEOLOGY AND GEOTECHNICS MODEL

One of the major challenges for BIM in underground construction projects is the representation of the ground at each specific project phase: from the initial design to the construction phase, when different geological conditions risk to be observed, compared to the expected ones. The importance of geology and geotechnics in tunnelling are far larger than in other infrastructures. In fact, the tunnel is totally embedded in the ground and geological and geotechnical models can be considered as part of the infrastructure itself.

A geological and geotechnical model was produced based on the boreholes of TELT database. Using the combination of BIM and GIS, a cross-analysis between the geological and geotechnical subsets and the imported structures is performed. The three-dimensional complexity is processed in the model to design better solutions according to the ground conditions and at the same time to control the unidentified risks. The 3D geological model was created with Leapfrog software. The construction of the model is based on an algorithm making possible a 3D interpolation of the boreholes information. This model not only facilitates geological, hydrogeological, geotechnical predictions and the uncertainties assessment, but also the creation of longitudinal profiles and cross-sections that can be exported for use in geotechnical numerical calculation software (Plaxis 2D/3D).

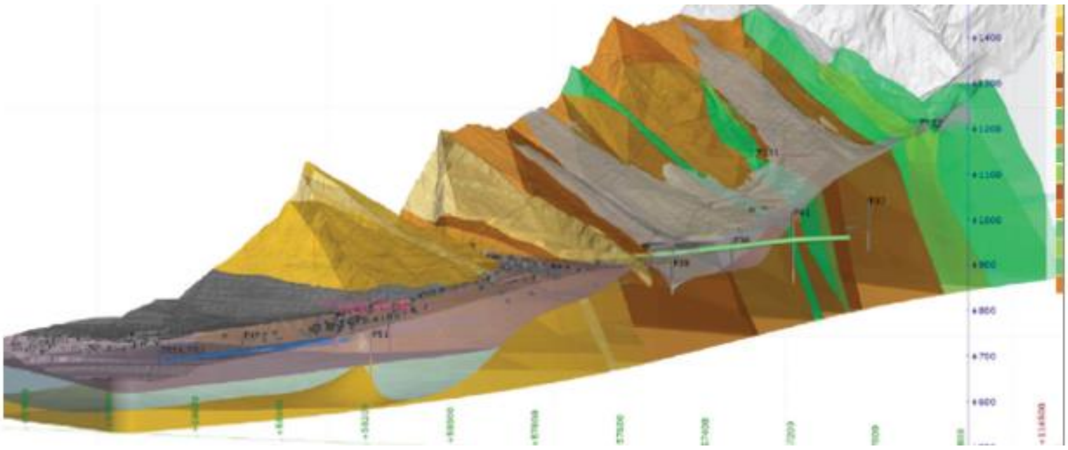

Figure 3. CO08 Tunnel - 3D ground model.

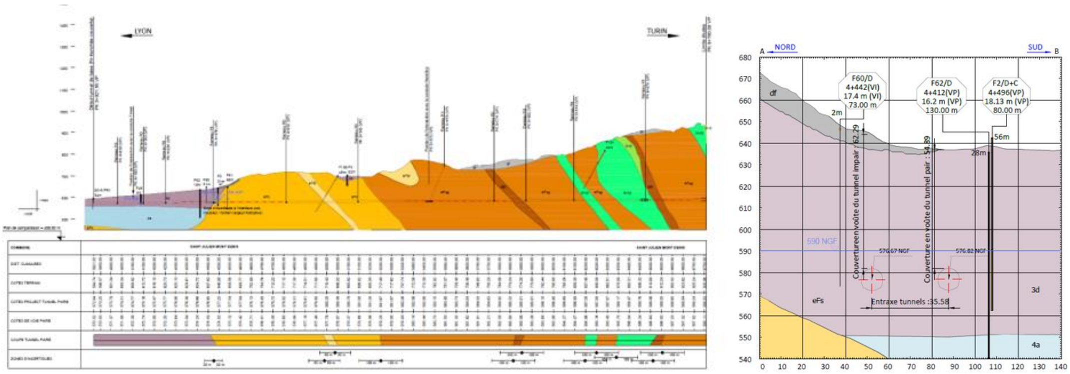

Figure 4. CO08 Tunnel - longitudinal profile and example of cross-section extracted from the 3D model.

5 STRUCTURAL MODELS

5.1 *Portal and ground improvement*

The portal structures and foreseen ground improvements were explicitly modeled in BIM in two different geo-referenced models that were then assembled with the same reference point. The explicit modeling of the portal allowed to check the conflicts, to realize the progress of the construction and to extract the 2D plans. The ground improvements model provided the coordinates, drilling and injection lengths of each Jet-Grouting column (Figure 5). This allowed a good prediction of the quantities and optimization of the injection zones in coherence with the calculations results.

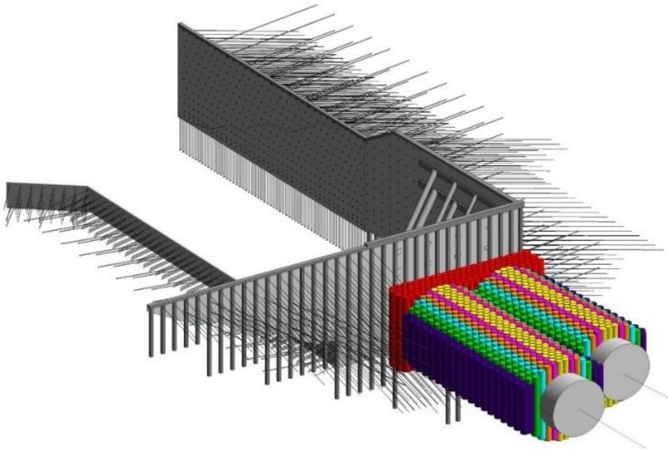
Figure 5. Portal and ground improvements model.

5.2 *Detail models of the support classes for the main tunnel*

In conventionnel tunneling, the choice and the design tunneling support classes are heavily influenced by the encountered geological conditions (i.e., discontinuities) and stand-up mechanical parameters of rock mass. Seven tunneling support classes (S2, S3a, S4, S5a, S3b, S7(ZNT), S7(ZT)) have been defined to ensure the stability of the tunnel along the entire alignment depending on the expected geology and rock mass behavior. All tunneling support classes have been modelled in BIM. The main supports are presented below (Figure 6):

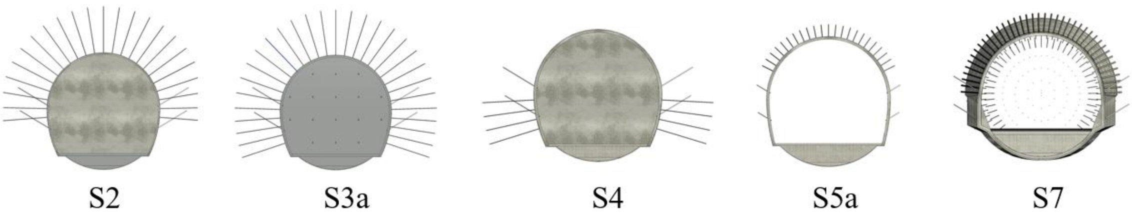

Figure 6. Main tunneling support classes.

Figure 7 shows the S7 support: the most complex and heaviest support class, which will be applied in soft ground. Figure 8 shows an example of the internal defined properties sets for the umbrella pipe.

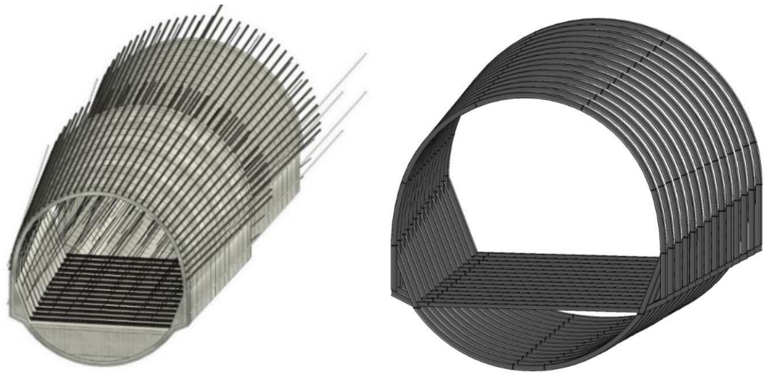

Figure 7. BIM model S7 support class and detail 3D model of the steel ribs.

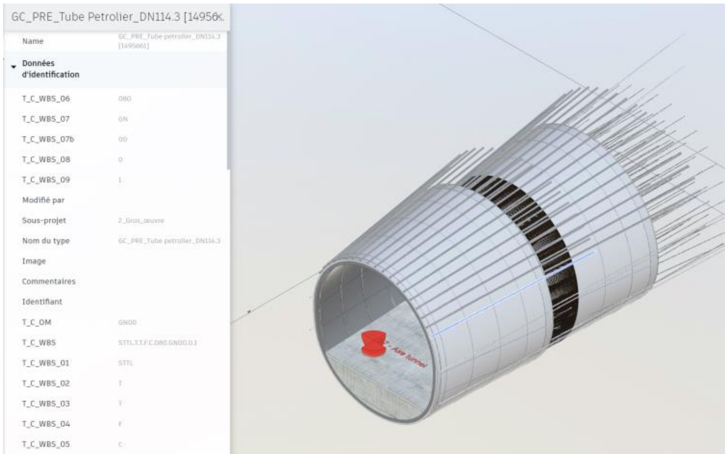

Figure 8. Example of the internal defined properties sets for the umbrella pipe

5.3 *Master federated model*

TELT's specifications require that the weight of the deliverables transmitted in the form of files should not exceed 200 MB to facilitate data management. To meet this requirement, the tunnels models need to be cut into 1 km long segments.

Figure 9 shows the portal area with the ground improvements and the first kilometer of twin-tunnels. A different color is associated to each tunnel support class in order to quickly identify the support profile applied along the tunnel alignment.

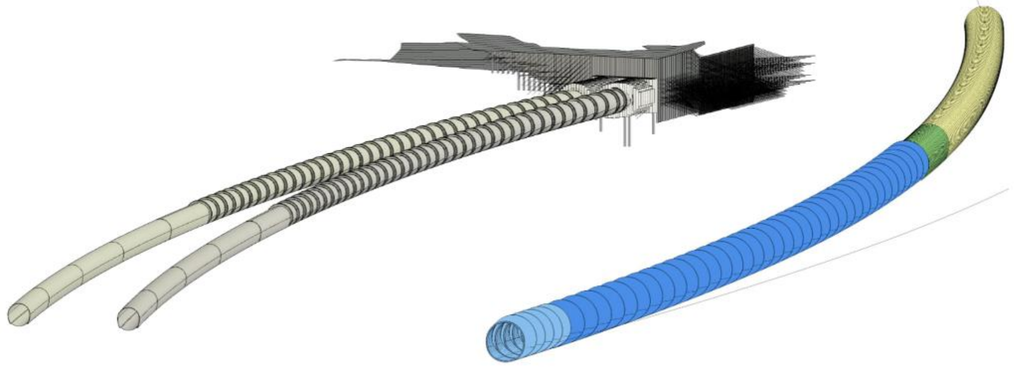

Figure 9. Master federated model with the portal area and Master federated model with the distribution of the support classes for the first kilometer.

6 DESIGN SUPPORT ACTIVITIES

6.1 *2D/3D models: detail drawings*

The 2D drawings (geological longitudinal profile, geological cross-sections (Figure 4), ground improvement plan, and support profiles) (Figure 10) are directly extracted from the BIM models. The 3D model was helpful to identify and solve geometrical conflicts in particular for complex geometries (i.e., interface between ground improvements at the entrance and tunnels alignments) and tunnel support profiles (see Figure 7).

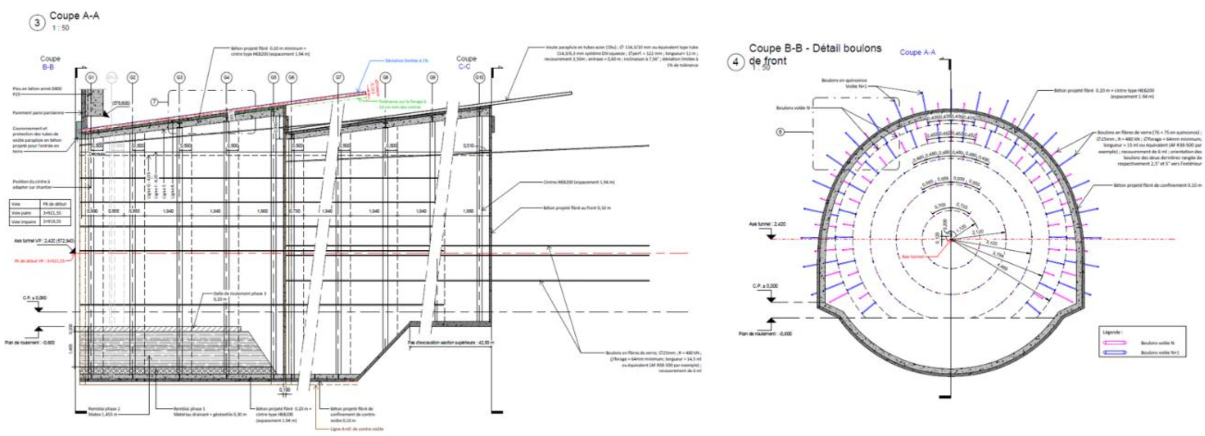

Figure 10. Example of a 2D drawing extracted from the BIM model

6.2 *4D/5D models: construction scheduling and sequencing*

The 4D BIM model for the civil engineering structures (main tunnel, cross-passage, Jet-Grouting and portal) is created by linking the 3D model to the construction schedule. It is used as the basis for 4D simulations, visualizations, analyses, and optimization work for the feasibility of the construction planning. The 4D model is regularly adapted to suit the requirements of the construction site and to optimize the construction process.
The 5D model is generated from the 4D model by inputting the contract prices contained in the BoQ (Bill of Quantities). It is then possible to generate performance and progress reports.

6.3 *BIM modelling and numerical modelling interoperability*

During the design studies, Pini tested the interoperability between Revit (BIM) and Plaxis 3D (FEM). The BIM3D models facilitate the FEM3D modelling of complex geometries, such as the truncated cone shape of the S7 support class. To date, for the structures part of the FEM3D model, the BIM-FEM interoperability currently consists of an exchange of geometric information. It was possible to import the tunnel geometry as surfaces and lines in ".dxf" format.

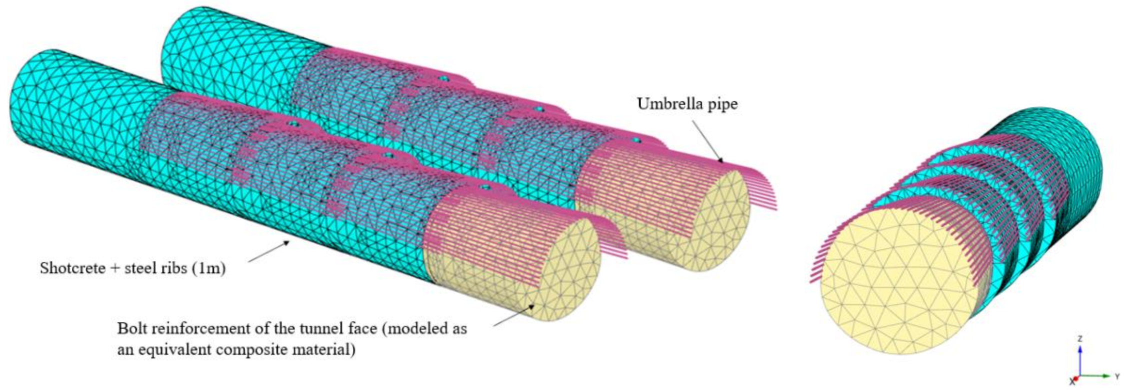

Figure 11. BIM-FEM interoperability with Revit and Plaxis 3D, Plaxis 3D model of the S7 support class

7 COMMUNICATION

Multidimensional photo-dynamic simulations allow the visualization of activity planning in time (4D) with costs (5D). The creation of this type of visual document is a use resulting from a good implementation in the models of the levels of information (LoI) and the codification of the project, allowing to link each element to its price and to its evolution in time. In this way, the creation of multidimensional simulations becomes automatic. These simulations allow a complete understanding of the evolution of the project, being able to visualize the evolution of the costs with the evolution of the project, comparing it with the real evolution of the project.
These technologies also allow to communicate with the public with videos, augmented reality, and virtual reality headsets.

8 CONCLUSIONS

The main conclusions can be drawn from the current progress of the project with regard to BIM:
- There is a need to create a uniform project structure (WBS) about the activities of the construction program and the elements of the BoQ,
- Conflict checking using the 3D model is, if used correctly, a very appropriate instrument to identify execution problems in time (i.e., tunnels and cross-passage junctions),
- 4D and 5D linking is a challenge that requires the corresponding systems. However, if successfully linked, it is a powerful project management tool,
- BIM models, if used correctly, allow direct output of 2D drawings with good graphical output
- Geological BIM models are a valuable tool for design, to identify possible uncertainties, to better distribute support classes along the route tunnel and to extract the necessary calculation cross-section,
- The BIM-FEM interoperability is a significant help for the modeling of structures with complex geometries. Nevertheless, the interoperability between these two tools still needs to evolve to facilitate the import of BIM models into FEM3D models (Plaxis 3D).

9 REFERENCE

Daub, 2019. Digital Design, Building, and Operation of Underground Structures BIM in Tunneling