Application of BIM in construction management of railway tunnel by virtual technology

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Abstract. The building information modeling (BIM) methods for construction management of railway tunnel, including naming rules of structuralized components and modeling precision requirements are studied by means of BIM technology. The methods and advantages of visualized design of 3D model of construction technologies for railway tunnel are explored. The methods for deducing and optimizing 4D model of construction of railway tunnel are studied. The automatic construction quantity calculating method based on BIM software is established. The construction practices show that the BIM technology can improve the construction scheme and technology management, and can provide visualized version for construction organization and management decision.

1. Introduction
The construction of railway tunnels is a highly dynamic process. In particular, the construction of complex lining tunnels with mines has many working procedures, complicated process transitions and staggered construction, which have high requirements on on-site progress management, engineering quantity calculation and technical quality inspection. At present, the technical means of on-site progress management is relatively backward, and the progress of the image in two-dimensional horizontal cross-sectional drawings is still mostly used. Therefore, the spatial relationship of on-site construction procedures can not be truly represented and it is difficult to accurately represent the construction dynamic process of multiple working surfaces. At the same time, on-site technical delivery is generally two-dimensional CAD drawings, on-site construction workers limited capacity of knowledge map, uneven, on-site technical difficulties.

Based on the 3D visualization digital model, BIM visualization virtual simulation technology uses digital simulation to simulate 3D geometric and non-geometric information (such as progress, material and mass) of the model [1]. By creating a construction BIM model for engineering-oriented structured objects, the body of the engineering structure is visualized as well as the difficulties of the construction scheme. At the same time, adding the time dimension into the model, simulating the construction process and realizing the virtual construction of the project. [2-3] Therefore, visual simulation based on BIM technology provides a breakthrough for the innovative development of tunnel construction.

2. Construction of BIM model for tunnel construction
According to the design, construction method, process and so on of composite lining tunnel construction by railway mine law, object-oriented BIM model component library of tunnel construction is developed. The so-called object-oriented modeling method [4], namely dividing the different components according to the spatial relationship of the tunnel structure, defining the spatial shape and information attributes of the components, and finally forming the model by assembling the components, such as Figure 1.
The components of the BIM model for composite lining tunnels can be divided into six major categories: advance support, initial support, secondary lining, inverted arch filling, drainage prevention and groove [5,6]. Model member naming rules use "component type + component type (rock level, lining type)." The surrounding rock level of the tunnel is divided into six grades Ⅰ ~Ⅵ. Under each grade of surrounding rock, it is divided into different lining types and expressed in English letters. Due to limited space, the definition of grade V rock and a, b lining type of component naming example, such as Table 1. Furthermore, for the detailed structure of components, the modeling needs to consider further structural decomposition, so as to design standardized components. Detail structure naming should also use the "construction category + construction type" rules, and construction type generally should use the "specifications" parameters. The following grille steel frame, for example, the detailed structure of the decomposition, such as Table 2.

Table 1. Components of BIM of the composite lining of tunnel

| Component categories | Name Example 1     | Name Example 2     |
|----------------------|--------------------|--------------------|
| Advance support      | Lead small catheter| Lead small catheter |
|                      | -Va                | -Vb                |
|                      | Pipe shed - Va     | Pipe shed - Vb     |
|                      | Spray concrete - V | Spray concrete - V |
|                      | Hollow anchor - V  | Hollow anchor - V  |
|                      | Mortar anchor - V  | Mortar anchor - V  |
|                      | Steel mesh - V     | Steel mesh - V     |
|                      | Section steel - V  | Section steel - V  |
|                      | Steel grille - II | Steel grille - II  |
|                      | Arch wall - V      | Arch wall - V      |
|                      | Inverted arch - V  | Inverted arch - V  |
|                      | Floor - II a       | Floor - II b       |
| Inverted padding     | Inverted padding   | Inverted padding   |
|                      | - Va               | - Vb               |
| Drainage             | Waterproof board   | Waterproof board   |
|                      | Water stop         | Water stop         |
|                      | Drain board        | Drain board        |
|                      | Center groove body | Center groove body |
|                      | Center ditch cover | Center ditch cover |
|                      | Side trench body   | Side trench body   |
|                      | Side ditch cover   | Side ditch cover   |

Table 2. Structural components of steel grille

| Component categories | Component name | Detail structure | Structure named |
|----------------------|----------------|------------------|-----------------|
|                      |                |                  |                 |
The key of BIM modeling is to develop component repository. The definition of component mainly includes four aspects: component naming, component coding, modeling precision and information granularity, among which the information granularity includes geometric information and non-geometric information. Modeling accuracy refers to the unit size of the component in the model. The modeling accuracy of each component in the tunnel construction BIM model should meet the requirements of construction process management as follows.

- Advance small catheter, pipe shed, hollow bolt, mortar bolt component units, should be a ring component form, the adjacent two rings are plum-like arrangement;
- Steel mesh, steel frame, grille steel frame unit, should be a ring component form;
- The unit of shotcrete should be according to the longitudinal length of the excavation step, the difference between the different surrounding rock level is large, generally 0.5 ~ 3.5m;
- Inverted arch filling, floor, inverted arch and inverted arch waterproof unit member units, should adopt the construction of the mold building length, usually 6 ~ 8m;
- Arch wall unit, should be molded longitudinal length, usually 10 ~ 12m.

3. Application of BIM in Tunnel Construction

3.1. 4D virtual construction.

4D virtual construction is to use virtual simulation environment of Autodesk Navisworks to add time dimension to the 3D geometric space model and to deduce the actual construction process. Specifically, the BIM model is associated with the construction organization schedule to progress-driven virtual simulation of the model.

Specific technical routes are as follows:
- Autodesk Revit to create 3D digital model, given the construction process attributes of each component parameters;
- project preparation process time task data source;
- Navisworks integration model and process time data source, Virtual Construction of Virtual Models in a Virtual Environment. At the same time, real-time process interaction, virtual deduction construction program, dynamic inspection program feasibility and existing problems, optimization and adjustment of construction equipment, technology. Figure 2 shows the BIM-based virtual construction program flow.
Figure 2. Process of virtual construction program by BIM

Figure 3 (a) shows the tunnel 4D virtual construction process, dynamic construction simulation of all structural nodes of advance support, initial support, inverted arch filling and secondary lining. Figure 3 (b) shows the construction schedule information and the bar graph, for each component of the construction flow section, the definition of time.

The construction sequence and time nodes of all components can be clearly seen from the figure. By comparing and analyzing the status of the construction plan and the actual construction progress, the project manager can dynamically control the construction progress in real time, determine the best construction sequence and time nodes, and quickly adjust the construction Resources, at any time for the development of materials procurement plan to provide timely and accurate data support, project cost control and provide technical support to achieve project refinement construction management.

Sunday 7:09:00 2014/2/2 Day=29 Week=5
DgK68+62~DgK68+700 Part construction simulation(root) [60%]
  Inverted arch filled concrete-stage10 [Structure 29%]
  Initial support-stage15 [Structure 29%]
  Second liner-stage4 [Structure 9%]

Figure 3 (a) 4D virtual construction (section)

Figure 3 (b) Crossing figure of the construction schedule
3.2. Program and method of visualization of the submitted.

Traditional two-dimensional CAD drawings to express engineering structure node design, often need to plan a combination of multiple profiles in order to express clearly. However, based on the three-dimensional digital model, BIM truly expresses the spatial geometry, position and function of the nodes of the engineering structure, makes the design of the complex space more intuitive, realizes the effect of the model "what you see is what you get," and can perform 360 degrees Visualization of the visual angle\(^{(12)}\) reduces the difficulty of construction workers in understanding drawings and effectively avoids construction errors caused by misunderstanding of drawings.

The lining ring of the composite lining tunnel shall be provided with a buried rubber water-stop band, and the longitudinal construction seam shall be provided with a buried steel edge rubber water-stop band. Figure 4 (a) is a CAD diagram, Figure 4 (b) is a BIM model, through the comparison between the two, the use of three-dimensional model on-site construction workers and teams technical results are significant.

Using BIM virtual simulation technology, the three-dimensional display of construction node construction method is adopted, and the structural design and construction scheme become more intuitive, which is convenient for construction workers to understand and use. By using Autodesk Revit software to create the construction BIM model and defining the "stage" construction sequence of components, the model is imported into Autodesk Navisworks software and a virtual simulation environment is set up to show the construction methods of the model for visualization. Figure 5 is a V stage rock tunnel using three steps seven excavation method and Figure 6 is the abutment into the hole CD method excavation method.

![Figure 4 (a) Plan of the water-stop by CAD](image)

![Figure 4 (b) Three-dimensional model of the water-stop](image)
3.3. Engineering dynamic accounting.
In the process of construction, according to the two-dimensional drawing calculation engineering quantity is very complicated, redundant and waste a large amount of manpower and material force, and the accuracy is generally not well, has great influence to the engineering measurement. However, the BIM digital information model has the accurate three-dimensional volume and the construction progress, which can quickly acquire the stage engineering quantity $^{[13]}$.

The specific method is as follows:
- Build a partial project BIM model with revit, and give the model component's body weight and construction stage attribute information;
- According to the actual construction status, count the current construction stage sub-item model body weight list;
Refer to the rule of engineering formula for calculating dimension formula and generate part of the project quantities from the model volume.

For example, Figure 7 is a model IVb tunneling step model in which the axial length of the initial support, the inverted arch and the inverted arch are 6 meters and the axial length of the arch wall is 12 meters.

4. Conclusion and discussion

At present, the application of BIM technology in tunnel engineering is still in the exploratory stage. According to the structural nomenclature of construction components and the precision requirements of process management, BIM model of tunnel composite lining construction is established by using the three-dimensional modeling method oriented to engineering entity objects, which can assist 3D visual design of tunnel construction organization and 4D Virtual Construction Management.

Based on the BIM visual simulation technology, the 3D model visualization design of tunnel construction technology scheme and the 4D model virtual construction deduction and optimization of tunnel construction scheme and the method and process of automatic calculation of the project volume are established. It will provide a reference for the practice and promotion of BIM technology in tunnel engineering.

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