BIM-based ventilation shaft construction schedule simulation and plan optimization

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Abstract. In order to solve the problems of multiple construction links, mutual influence and restriction, and tight construction period of the ventilation shaft under complex geological conditions, the BIM technology is used to realize the three-dimensional parametric modeling of the Nanhu ventilation shaft project from geology, main structure and main construction equipment, etc. Simulating the construction schedule, formulating a reasonable schedule and optimizing the construction plan are of great significance for accelerating the construction schedule, controlling construction risks, and striving to make the Nanhu air shaft project put into use as soon as possible.

1. Introduction
At present, subway construction in various places has entered its peak period, and the design work must not only face the control factors of geology and surrounding environment, but also match the construction period, cost and safety. In recent years, in order to reduce the risk of shield tunnel entry and exit in the water-rich sand layer, the “tunnel first and well later” construction scheme is usually adopted to reduce the number of shield tunnel entry and exit times and reduce construction risks.

As a brand-new technology, BIM originated in Western countries. It started relatively late in China. It replaced the traditional two-dimensional view design with the three-dimensional model’s horizontal, vertical and cross-sectional view linkage design method, and changed the three-dimensional design thinking. It becomes a visible three-dimensional object, providing a real three-dimensional program visualization design environment.

In this paper, combined with the construction process, using BIM model, through the virtual reality technology to carry out a comprehensive interactive intuitive display of the scheme, to consider the rationality of the scheme, and to carry out the construction schedule simulation and scheme optimization of the air shaft under complex geological conditions, which has important exploration and application value.

2. Project Overview
The ventilation shaft between Nanzhuang Station and Huyong Station of Line 2 is located on the west side of Zidong Avenue and the south side of Jihua West Road in Foshan City, at the intersection of an existing road and a planned road. The current road width is 8m, and the planned road width is 24m. Zidong The width of the red line of the boulevard is 50m. The planned road has not been implemented. The area around the section is Chongmei Village. There are many surrounding buildings and the site...
along the line is relatively tight. The middle air shaft is a five-story three-span box structure. The burial depth of the bottom of the wind shaft is about 34.96m, and the overlying soil above the top is about 4.5m.

In the original design, the foundation pit adopts an open cut and smooth structure. The wind shaft is 26.4m long and 24.7m wide. Considering the shield tunneling, the depth of the foundation pit is 35.159m, and the access depth of the ground wall is 6m. The enclosure structure adopts 1.2m underground continuous wall + 6 vertical concrete diagonal braces, and the shield tunnel is required to pass after the main shaft construction is completed. In the later stage, the construction progress of the ventilation shaft was delayed due to the expropriation and demolition. In order to avoid the risk of long-term shutdown of the shield machine, after the enclosure structure was completed, the shield passed through the intermediate ventilation shaft. After the shield construction was completed, the shaft was excavated and supported. Protection, that is, "tunnel before well".

3. Specific construction procedures and control difficulties of the tunnel first and well scheme

3.1. The specific construction process of the scheme

The wind shaft structure adopts the cover-dig and top-down construction method, and the excavation opening (ventilation opening in the later period) is reserved during the construction process. After the construction of the fan structure is completed, the connecting channel is constructed by the hoisting method. The specific construction procedures are as follows: 1) After the site is leveled, reinforce the foundation with jet-grouted piles, construct the enclosure wall and the middle column. The middle column can be a lattice column or a steel pipe column, which will be used as the main structural column frame in the later stage. 2) Excavate the foundation pit to 0.5m below the bottom surface of the roof, cut out the continuous wall at the boundary between the retaining wall and the roof, construct the roof and the roof beam, and lay the roof waterproof layer. Excavated holes are reserved at the top plate, which will be used as vents later. 3) Excavate the foundation pit from top to bottom, and construct the main structure to the bottom plate in sequence. The excavation openings are reserved for each layer. The excavation openings are air duct openings. The bottom plate reserved connecting section air openings, and reserved steel connectors for later construction. The main reinforcement of the side wall of the air duct is connected. 4) After the air shaft is filled with water to a certain elevation, the shield tunnel passes under the already constructed air shaft, and the pipe segments connected to the air shaft are made of steel pipe. 5) Excavate the soil at the air duct from the bottom plate from top to bottom, construct the side wall in layers, and reserve a steel connector at the bottom of the side wall to connect with the main reinforcement of the subsequent side wall. The construction is divided into 3 sections. 6) After the construction of the side wall of the air duct is completed, the steel pipe slices are removed in turn to complete the whole project.

3.2. Difficulties to control the program

Adopting the tunnel first and then the well scheme, the design and construction of the intermediate ventilation shaft enclosure structure in the Nanhu section have the following difficulties:

(1) There are many construction links in the first tunnel and then the well, which influence and restrict each other. During the construction process, the measurement, drilling, blasting, risk removal, support, slaming, lining, grouting and other operations are carried out in sequence, and various interference factors may affect some of these links, causing disadvantages in the project implementation stage Status.

(2) The engineering geological conditions are poor. Above the excavation surface of the foundation pit, there are mainly fill layers, silt layers, cohesive soils, silt and round gravel layers. The silt and round gravel layers are thicker, and the air shaft is first. The surrounding rock protection measures must be strengthened during the construction of the tunnel shaft to increase the initial support workload such as bolting and shotcreting. With the excavation of the foundation pit, the wall toe above the shield hole deforms into the foundation pit, forming a connection between the segment and the
ground. The seepage channel between the walls is enlarged, and measures must be taken to prevent water and sand in the foundation pit to ensure a safe construction environment.

(3) The construction period of the Nanhu Ventilation Shaft Project is tight. In order to enable the Nanhu Ventilation Shaft Project to play its expected social functions and economic benefits as soon as possible, the construction plan should be optimized and a reasonable construction implementation sequence should be formulated.

From the above-mentioned difficulties in the management and control of the construction schedule of the ventilation shaft before the tunnel under the complex geological conditions, it is of great significance to formulate a reasonable schedule and optimize the construction plan to accelerate the construction progress, control the construction risks, and strive to make the Nanhu ventilation shaft project put into use as soon as possible.

4. Construction schedule simulation and analysis

4.1. Parametric modeling
In order to simulate the progress of the Nanhu air shaft construction plan, it is necessary to use Autodesk Revit software to establish the following three types of models: The structural model includes tunnel segments, supports, enclosures, etc., geological models, construction equipment models, excavators, etc.

4.1.1 Structural model. The structural model includes tunnel segments, supports, enclosures, etc. The tunnel shield section adopts the prefabricated segment assembly technology. Each ring consists of six (3 standard blocks + 2 adjacent blocks + 1 capping block) tube segments. The center line of the tunnel is formed by a combination of plane linearity and longitudinal linearity. The linear fitting of the plane and longitudinal section of its different parameters are completed through typesetting. Since the maximum slope of the Nanhu section is 27‰, according to the requirements of the fitting curve, the typesetting determines that the linearity of various segments after the combination is closest to the tunnel design axis. The foundation pit support adopts the reinforced concrete support combination form, and a total of 6 support systems are designed for the foundation pit. The envelope structure adopts 1200mm thick underground continuous wall, the material is C35P6 underwater concrete, HPB300, HRB400 grade hot-rolled steel bars, the top elevation of the wall is +1.407, the bottom mark of the continuous wall is -38.248~ -41.248, and the depth of the underground continuous wall is 41.148m~ -44.148m (A05~A7, A12-A14) (3.7m into the rock), the structure model is shown in Figure 1.

Figure 1. Structural model.
4.1.2 Geological model. The stratum passed by the interval tunnel is mainly composed of fill, silty soil, silty silt, silt, fine sand, medium, coarse sand, round gravel, silty soil, soft plastic clay, plastic clay, mudstone, powder. It is composed of sandy mudstone, with complex geological conditions and large slope. The geological model is shown in Figure 2

4.2. Construction simulation

The Navisworks software was used to simulate the progress of the construction plan, and the revit model of Nanhu air shaft was exported as a .fbx format file. The FBX file is a convenient data format used by Autodesk for film and rendering. In this format, relevant data such as 3D models, materials, lighting, and rendering information will be retained to facilitate conversion between different film and television production tools. Create a scene file in Navisworks and open the air shaft model .fbx format file.

Use Excel to edit the time task item of each construction step, including task name, task type, start time, end time, ID serial number, etc., export the time task item data source CSV file, import it into Navisworks, and the air shaft FBX model Using certain automatic association rules, the model components are associated with the time task items in a one-to-one correspondence, and the 4D virtual construction of the time task item-driven model is performed in the Timeline virtual simulation environment.

Use Navisworks software to make construction simulation animation. Construction simulation animation can be called 4DBIM to a certain extent. 4D is 3D plus project development time, used to study buildability (constructability), construction planning and optimization tasks and the work sequence of the next subcontractor. Through this kind of construction simulation, the production cycle can be well controlled, personnel and materials are prepared in advance, and the waste of construction period, materials and manpower can be effectively reduced.

5. Construction plan optimization

The construction simulation found that there is a risk of water seepage during the excavation of the seventh layer of soil. In order to avoid the risk of water seepage, MJS+ grouting reinforcement was carried out on the <3-4> round gravel layer outside the ground connecting wall during site construction. If the reinforcement effect is not good, you can continue to use WSS grouting for supplementary reinforcement.
6. Summary
The construction plan of the Nanhu air shaft has an important impact on the construction schedule, construction safety, and construction cost. Before the project starts, a three-dimensional model is established based on the relevant data of the Nanhu air shaft project. Through the construction schedule simulation, the theoretical prediction of the construction period can be realized. And the optimization of construction organization can be realized through optimization and adjustment of relevant parameters.

This research work provides an effective decision-making reference basis for the Nanhu Ventilation Shaft Project, and the relevant conclusions or suggestions can further play a role in the project implementation stage. At the same time, the established model and construction simulation method can also be used in other similar projects.

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