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Application Research on Construction Management of Urban Underground Utility Tunnel Based on BIM

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Abstract: The urban underground utility tunnel is a new mode of municipal engineering planning and construction. By summarizing the problems existing in the construction of municipal tunnel in China, we discussed the application of BIM technology in the construction of municipal tunnel. In addition, we analyzed the advantages of BIM software in the construction of municipal tunnel by using its functions of collaborative design, comprehensive design of pipelines, construction schedule and process simulation. The results showed that the application of BIM technology in the construction of municipal tunnel would improve the construction quality and project management level, and maximize the benefits in the construction stage, which would also provide ideas and technical support for the utility tunnel project planning.

1. Introduction

With the acceleration of urbanization development, it has become the trend of urban development to use utility tunnel to lay municipal pipelines, which is a structure and ancillary facilities that can accommodate a variety of pipelines and equipment in underground space [1-2]. By increasing the construction of utility tunnel, which can reduce problems such as construction damage to underground pipelines and improve the utilization rate of underground space. However, due to the special nature of the utility tunnel project, it has the characteristics of high construction difficulties, large input costs, many specialties, complicated geological conditions, high safety and reliability requirements. Besides, in the process of underground construction, there may be a collision with the municipal pipeline where have already constructed, and it may also involve many problems such as the construction of subway project.

Most relevant researches on utility tunnel both at home and abroad focus on the design of projects [3-4]. For example, Zong et al. [5] combined with specific engineering design to incorporate into a comprehensive high-tech industrial zone in Qingdao, where the municipal pipelines in the utility tunnel were analyzed in detail, and the combination of utility tunnel and direct burial were finally determined. Wang et al [6] made a key analysis on the design issues of drainage system, ventilation and fire protection of the utility tunnel. Cong [7] analyzed the cause of fire and the fire situation of the comprehensive pipe trench around the CDC in Guangzhou. Thus, the fire protection system of the utility tunnel was designed. In addition, some scholars designed the auxiliary structure of the underground utility tunnel project [8-9], financing and benefits [10-11] and other aspects. In recent years, some achievements have been made in the urban underground pipe network informatization and BIM technology-based utility tunnel development. Such as Zhang et al. [12] introduced GIS technology into the management of water supply pipe network in Xi'an and realized the three-dimensional visualization of pipe network water pressure by integrating plane labeling, two-dimensional coloring and three-dimensional solid map, which provided scientific basis for the optimal dispatching and construction planning of water supply network; Park et al. [13] developed an engineering system integrating BIM and GIS to estimate the cost of the project in order to choose the best route and further improve the project construction method. Some foreign scholars have proposed to establish automatic alarm [14], environmental monitoring [15], structural monitoring [16], video surveillance and other management systems from the perspective of security operation monitoring to realize real-time monitoring of underground pipelines. In addition, some researches have proposed an underground pipeline management scheme based on visualization technology, and applied it to urban underground utility tunnel. In Zhuhai city, the Hengqin municipal utility tunnel project provides information on pumps, fans and other equipment based on BIM system in order to facilitate timely positioning and maintenance of faulty equipment. Research on disaster management related applications shows that it is of great significance for preventing and controlling dangerous fires and deploying fire forces. Collecting information through the BIM technology application process and storing it in a compatible database facilitates the development of various tasks in the operation and maintenance management phase, such as system commissioning and finishing, quality control and assurance, energy management, maintenance and management, etc.

BIM technology has many advantages such as high degree of visualization, simulation rehearsal, and good coordination compared with traditional technology. It has been widely used in civil construction projects. However, there are few studies on the application of BIM technology in the construction of utility tunnel. Relevant technical theories need to be improved and supplemented. This paper attempted to analyze the application of BIM technology in the construction management of urban underground utility tunnel, discussed the engineering measurement and collaborative design of BIM technology. Besides, functions such as collision detection and construction site layout played a role in the construction of utility tunnel, thereby saving operation and maintenance costs of utility tunnel and improving construction efficiency.

2. Main problems in the construction of utility tunnel

2.1 Imperfect construction standards

Germany, France, Japan and other countries have started the construction of utility tunnel earlier. As early as 1832, Paris began to build underground utility tunnel. China's national conditions are different from other countries. We cannot blindly imitate the planning of cities in foreign countries. In addition, China’s economic conditions cannot support large-scale construction of underground utility tunnel engineering. Therefore, China started late, laws and regulations of which were not detailed enough, and the management system for underground utility tunnel projects was also not perfect [17]. From “Technical code for urban utility tunnel engineering” (GB50838-2015), it can be seen that the requirements and regulations for the cable duct are not detailed enough, and the circular section of the shield in the construction method is not clearly defined, which also makes it impossible to have a basis for the design and construction of utility tunnel [18].

2.2 Large investment cost

The construction of the utility tunnel needs to be planned as a whole, due to many reasons, the cost is very high, and the operation and maintenance are complicated at the later stage. Take the Liupanshui utility tunnel as an example, the cost is about 80 million/km, in which civil engineering cost is about 45-50 million/km [19]. As the cost of the project unit is relatively high for the government, it is still unable to meet the large-scale promotion and construction. Since 2014, the government has strongly supported the PPP model to promote investment in the construction of utility tunnel. However, the fact that the promotion of this model has not yet been popularized, the policies supported by the state are not specific enough, and investors are afraid to invest blindly, so that the construction of the municipal utility tunnel can only rely on government financial investment and lack of corporate investment.

2.3 Difficult construction and coordination

There are many unforeseen circumstances will occur during the construction of the urban utility tunnel, such as complicated geological conditions, collisions with the original municipal pipelines, and how the pipelines enter the ditch and so on, these problems will delay the construction period. In addition, the lack of experienced engineers and technicians can cause problems in the construction process. As the management system has not yet been perfected, most cities have not yet established an effective communication and coordination mechanism among pipeline ownership units. Therefore, it is difficult to reach a unified opinion on construction cost sharing, operation and maintenance, etc., which also hinders the development of the tunnel.

3. Application of BIM technology in utility tunnel engineering

3.1 Application point of BIM technology

3.1.1 Collaborative design and comprehensive design of pipelines. All professional and technical personnel share the model information of this major in a central platform for collaborative design [20]. The collaborative design of BIM should be presented in a three-dimensional model, it also requires the designer to attach the building component attribute information to the model. After the model is built, the software will generate the corresponding flat profile view and use the MEP plug-in in the same model. The layout of the piping system can be used to express the structure and pipeline using a 3D model. There are many pipelines and equipment arranged in the utility tunnel, the previous method was to superimpose the drawings and adjust the intersections of the pipelines. This method has high requirements for the three-dimensional space capability of the technicians and the mastery of various professional knowledge, which is often prone to errors. Integrated BIM into pipeline design, each major is modeled and integrated in the same central platform, and the collision detection of components in the integrated body can quickly locate the point and make reasonable adjustments, which will improve work efficiency and facilitate coordination and cooperation among professionals as well as save construction costs [21-22].

3.1.2 Statistical engineering quantity. At present, the measurement and pricing software on the market, such as Guanglianda, Swell, and Luban, are mostly modeled on the basis of two-dimensional drawings, which wastes time, manpower, and is often prone to errors. Besides, when the site is being constructed, it is inevitable that the employer will make a design change. Traditional modeling software cannot update to the change information synchronously, but BIM software can transfer the change information timely. After the updating is completed, the automatic calculation of the engineering quantity is carried out and the table summary provides reliable data information for the cost budget and final settlement of account.

3.1.3 Construction schedule and process simulation. The construction of urban utility tunnel is a dynamic process. Due to climatic reasons, geological conditions, etc., the construction period may be delayed, so the grasp of the construction schedule is crucial. Traditional software can't vividly represent the schedule of the project. However, BIM modeling can integrate the 3D model and time schedule to show the simulation run of the 4D construction schedule. During the construction of utility tunnel, the interaction between the construction process and the team are well coordinated, which is the necessary work for the smooth construction [23]. Therefore, application of BIM technology can dynamically monitor the problems which are difficult to solve in the project and select the optimal plan.

3.2 Case analysis

3.2.1 Engineering measurement. Taking a section of underground utility tunnel project in Shanghai as an example, it is modeled separately by Luban software and Revit software. Fig.1 shows the model effect diagram of Revit software. We summarized the engineering quantities of each component and analyzed the measurement data of the two softwares.

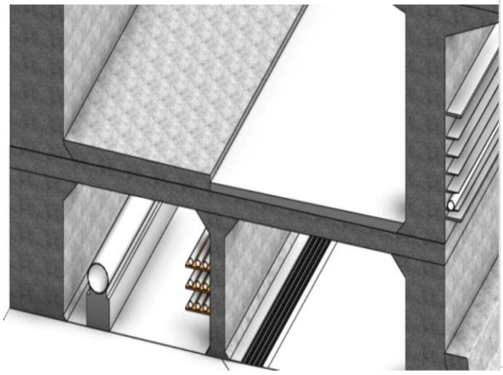


Fig.1. Model effects built with Revit software

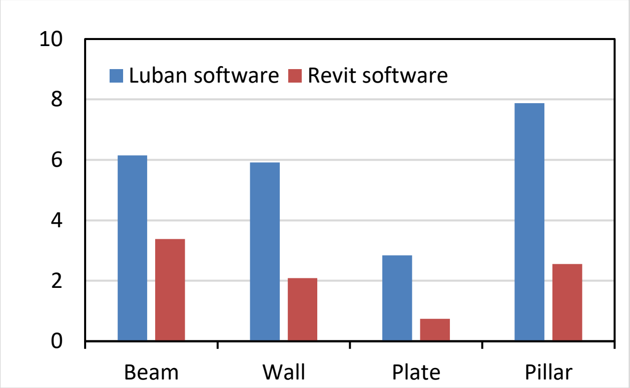


Fig.2. Actual deviation percentage of concrete quantity of each component

Table 1. Statistics of concrete quantity of each component

	Beam (m^3)	Wall (m^3)	Plate (m^3)	Pillar (m^3)
Luban calculation	400.55	285.00	435.51	150.66
Revit calculation	412.38	263.46	426.63	159.36
Actual quantity	426.79	269.08	423.49	163.54

As shown in Table 1, The actual project quantity is the data after completion and settlement for reliability reference, then calculate the degree of deviation between Luban software and Revit software measurement and actual engineering quantity. According to the data in Fig. 2, there is a small deviation between the project amount calculated by Revit software modeling and the actual project amount, indicating that BIM software is more conducive to the estimated budget and bidding work of the project, and maximizes the benefits for the enterprise.

3.2.2 collision detection. For utility tunnel projects, the use of BIM technology for collision detection has obvious advantages, and many problems in the design stage can be found, which are difficult to be found by the traditional single professional verification. After the modeling of each major is completed, all professional models will be integrated for collision detection and feedback to the design department for adjustment. The BIM collision detection function can accurately locate the collision points in the entire building model for technicians to adjust the components. As shown in Fig. 3, collision detection and adjustment can be carried out through the whole process, as well as optimized pipeline layout.

According to Fig. 4(a), Navisworks software can conduct collision detection of pipelines and accurately locate the collision point, then click the collision number to locate the specific collision location and make adjustments. The following Fig. 4(b) shows the adjusted Navisworks collision point model.

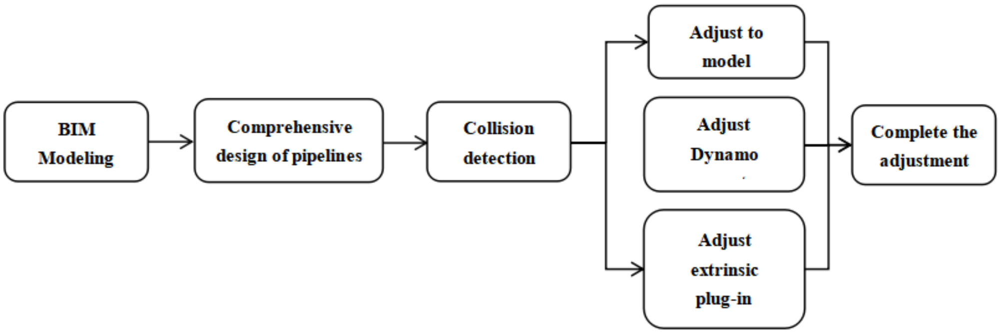
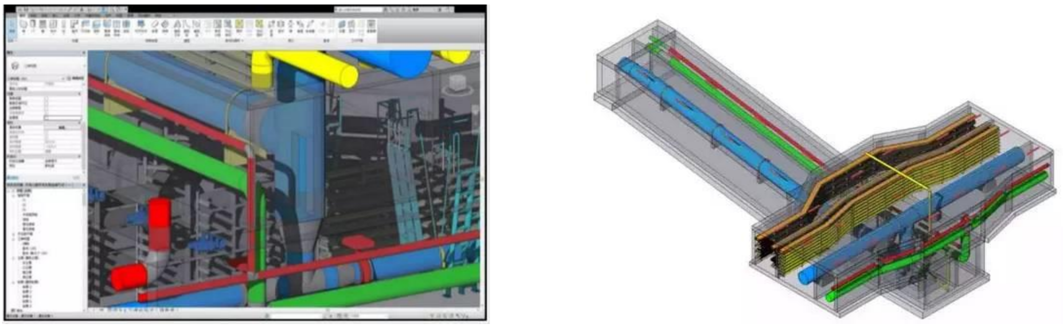


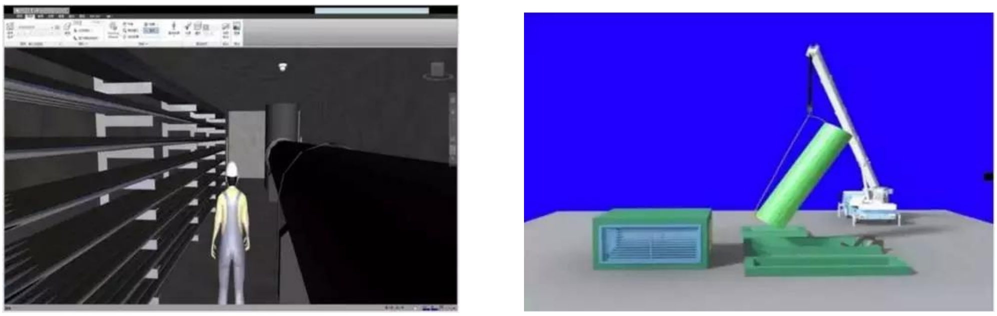
Fig. 3. collision detection workflow



(a)Collision detection (b) Adjusted model of collision point

Fig. 4. Navisworks collision detection and adjustment

3.2.3 Virtual wandering. After the completion of the utility tunnel project design, virtual wandering is used to demonstrate the design effect, so as to provide more intuitive process docking and organization for the project construction process. At present, many construction units require design and construction process to do BIM reporting, including virtual wandering, which has great advantages over traditional construction management in internal measurement of clearance height, large machinery and equipment approach simulation and so on. Fig.5 (a) is a clearance measurement inside the utility tunnel to facilitate equipment access and installation, Fig.5 (b) is a simulation of the installation of large diameter pipes to preview the possible situation. BIM software can greatly simulate the operation of the construction site and prepare for the safe entry of equipment and machinery.



(a) Measurement of clearance height (b) Large diameter pipe installation simulation

Fig. 5. Virtual wandering of utility tunnel construction

3.2.4 Construction site layout. The general construction site layout is that technicians conduct field survey, and then draw the site layout map with two-dimensional software according to the site experience. However, construction is not a static process, and the site layout changes before and after construction vary greatly. Nevertheless, technical personnel can dynamically express the layout changes of the site, normalize the construction and save construction costs through BIM software.

4. Conclusions

By studying the application of BIM technology in various stages of the construction and management of utility tunnel, the following conclusions can be drawn.

(1) The application of BIM technology in the construction process of the utility tunnel enables the collision detection of 3d models, avoids the information incompatibility of the traditional design mode, improves the coordination efficiency among various departments and departments, and saves time and cost for the project construction, thus maximizing the benefits. In addition, it is convenient for construction management, optimization of construction technology and control of construction progress, and can carry out visual technical disclosure, providing guarantee for the construction quality of underground utility tunnel.

(2) BIM technology is leading a new development direction in the field of engineering construction. The construction of urban utility tunnel based on BIM technology breaks through the technical bottleneck of traditional pipeline construction, discovers the existing problems in design and construction in advance, improves the construction quality and efficiency, and reduces the construction and operation cost. Besides, the model information is provided to the operation and maintenance management unit to improve the maintenance level of the utility tunnel, which will provide reference and technical support for realizing the informatization and intellectualization of underground utility tunnel construction and operation and maintenance.

Acknowledgments

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