Application of BIM Technology in the Construction of a ComprehensivePipe Gallery

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Abstract

The increase in urbanization rate in China has prompted the Chinese government to emphasize on the construction of comprehensive pipe gallery for utility placing. A comprehensive pipe gallery has many economic, social, and environmental benefits compared to the traditional way of laying utilities. Despite the many advantages, the construction of a comprehensive pipe gallery involves many factors which if not properly managed they can easily lead to rework, cost overruns, schedule delays, and loss. To solve the problems in the construction of the comprehensive pipe gallery, the application of BIM technology has become inevitable. Through BIM features such as visualization, clash detection, and simulation, this paper explains their application in the construction of a comprehensive pipe gallery using a case study in China. The results show that, the application of BIM in the construction phase improves design information, improves communication and coordination between the respective departments, saves time and cost, improves transparency, enables smooth negotiations for increased quantity and guarantees the construction quality. Furthermore, a BIM model creates a good foundation for improvement in maintenance level of the comprehensive pipe gallery.

***Keywords**: Comprehensive pipe gallery, Building Information Modeling (BIM), construction.*

1. Introduction

With the increase in the rate of urbanization in China, it has become a necessity to use comprehensive pipe gallery to lay municipal or private utilities[1]. A comprehensive pipe gallery refers to a public tunnel that uses the underground space of the city to lay communication pipelines, electric power pipelines, heating and cooling pipelines, water supply and, drainage pipelines, etc., in order to solve the problems of “cross-hitting” and “zipper-type maintenance” of pipelines in traditional laying method[2], [3]. Furthermore, the construction of comprehensive pipe gallery guarantees smooth flow of traffic, provides better protection of utilities from damages, corrosion, and impacts of their accidents to the people and environment, and improve the utilization of underground space[4], [5]. Despite the above mentioned advantages, a comprehensive pipe gallery is characterized by high construction cost, pipelines owned by different professional departments, construction difficulties, complex geological conditions and operation and management difficulties. Moreover, a collision between an existing structure such as other municipal pipe galleries and a new structure such as in the construction of a subway may occur[6], [7].

Due to the late start in construction of comprehensive pipe gallery in China, the research on comprehensive pipe galleries is still nascent compared to housing and roads projects. Most recent researches on comprehensive pipe galleries focused on the architectural and economics part such as planning, design, investment, sponge city and comprehensive pipe gallery project in PPPs [8]. Miao Xiangda et.al [9] detailed the mechanical characteristics and the design of soil-mixing wall pile construction method for a comprehensive pipe gallery in a weak stratum due to water by using a section of the comprehensive pipe gallery that required the pile work. Xuetong Wang et.al[10] summarized the situations, problems and countermeasures of urban utility tunnel projects based on PPPs and concluded that financing policies and risk management and allocation mechanisms are fundamental for utility tunnel project based on PPP success. In addition, some researchers designed the automatic fire alarm system[11], [12] and ventilation system for the comprehensive pipe gallery[13].

In recent years some scholars have published on the application of BIM technology in comprehensive pipe gallery and its integration to related technologies such as Internet of Things

(IoT), GIS, smart technology etc. for operation and maintenance of the comprehensive pipe gallery. Shu Tang et.al [14] conducted a review on the emerging areas of application, design patterns, limitations and future trend of integrating BIM-IoT devices in Construction Operation and Monitoring, Health and Safety management, Construction Logistic and Management, and Facility Management. Mingzhu Wang et.al [15] designed an integrated BIM-GIS utility management framework for improving and facilitating the information sharing process, utility management efficiency and decision-making. Isam et.al [16] designed a smart solution which sets up and improves the security and the collective governance system of comprehensive pipe gallery.

BIM technology features such as visualization, simulation, and parameterization [17] are very advantageous to the civil construction industry compared to traditional technology. However, despite the achievements mentioned above, there are still few studies on the application of BIM technology in the construction of comprehensive pipe gallery and a further improvement and supplementation of the relevant technical theories is required. This paper the analyzes the application of BIM technology in the construction phase of the comprehensive pipe gallery using the Huainan Zhongxing road-Chunshen avenue comprehensive pipe gallery as a case study. The comprehensive pipe gallery project information and difficulties are outlined and followed by the subsequent application of the BIM technology in solving the underlying challenges. Through BIM functions such as 3D model creation, clash detection, simulation and virtual wandering, the construction efficiency is improved and the use of BIM model in operation and maintenance will surely enhance the operation and maintenance level of the comprehensive pipe gallery.

2. Project Overview

Project details

Huainan Zhongxing road- Chunshen avenue comprehensive pipe gallery project is a project that consists of two comprehensive pipe galleries which are both laid at the center of the road at Zhongxing road and the other at Chunshen avenue located in Shannan district, Huainan city, Anhui province. The total length of both comprehensive pipe galleries is 6.33 kilometers. The details are as follows:

a) Zhongxing road comprehensive pipe gallery: It has a total length of 3.66 kilometers with an outer cabin size of 590cm x 400cm (width x height). It contains two inner cabins; a comprehensive cabin with a size of 310 cm x 330 cm (width x height) and a gas cabin with a size of 180cm x 330cm (width x height). It has 29 power cables of which 9 have 110KV and 20 have 10KV, 4 layers of telecommunication cables, 1 DN800 water pipe and 1 DN400 gas pipe. The typical cross section of Zhongxing road comprehensive pipe gallery is presented in fig 1 below

b) Chunshen avenue comprehensive pipe gallery: It has a total length of 2.67 kilometers. It is divided into two sections: one section is 0.97 kilometers long and the other is 1.7 kilometers long. They both have an outer cabin size of 590cm x 360cm (width x height) and two inner cabins. The comprehensive cabin size is 310cm x 290cm (width x height) and the gas cabin size is 180cm x 290cm (width x height). It contains 28- 10KV power cables, 4 layers of telecommunication cables, 1 DN800 water pipe and 1 DN400 gas pipe.

Project difficulties

Design challenge.

In this project, the design of the comprehensive pipe gallery project is not clearly detailed in the drawings provided. The design drawings have not provided detailed information for the power pipeline supports, the standpipe size, position and its support hangers. The design team has only provided a simple schematic diagram. This situation poses a challenge to the construction unit during material procurement and construction. The construction unit has to look for a better way to construct the supports and hangers of the pipelines and not according to the existing design drawings of the pipelines.

Construction challenge.

The upper part of the pipe joint of the comprehensive pipe gallery is arranged with air inlets, air vents, hoisting openings and escape openings. In this project, the design of the openings is not clear in some places hence there is a need to detail the design. Since the units of the exposed height of the opening is not given in the construction drawing, then it only means that the openings will be made according to the vertical section elevation and the height of the prefabricated cover plate will be equal to the level of the green belt. In fact, the wall around the opening has a minimum control height that is to be met and not to be poured into the pipe corridor. Setting the opening too high above the surrounding wall will make it not to be neither beautiful nor economic.

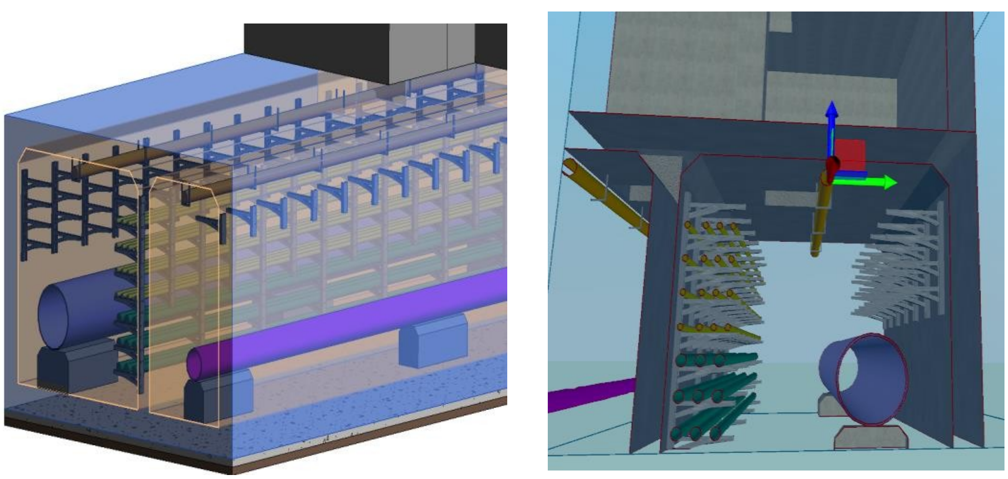
Installation challenge.

The comprehensive cabin in this project integrates power cables, telecommunication cables and water supply pipeline as well as pipelines necessary for the operation of lighting and monitoring hence the pipelines belong to different professionals. The installation process of these pipelines is not indicated on the design drawings therefore the construction unit must work out the detailed plan of the pipeline access corridor in advance and communicate with the construction and management department in order to avoid crossing of the pipelines or rework after the pipeline access corridor is completed and realize the target of the scheduled operation. An improper coordination of the construction and installation process of the respective pipelines makes it extremely easy to have schedule delays and cost overruns.

3. BIM Application

Supports and Hangers design.

Taking a section of the Huainan Zhongxing road- Chunshen avenue comprehensive pipe gallery, a BIM 3D model was created using Revit software. The creation of the BIM model enabled the determination of the shape, size, spacing and placing of the pipeline supports, standpipe size, its hangers size and spacing in a more realistic way. The spacing of the supports for the power pipelines was maintained as per the design specification but the length of the support in between 2m spacing was shorter since it only supported the 10kV power pipelines see Figure 1(a). This change in support shape has helped to save material, installation time and cost while still optimizing the serviceability of the structure. The standpipe was placed at a position that will not obstruct the escape hatch see Figure 1(b).

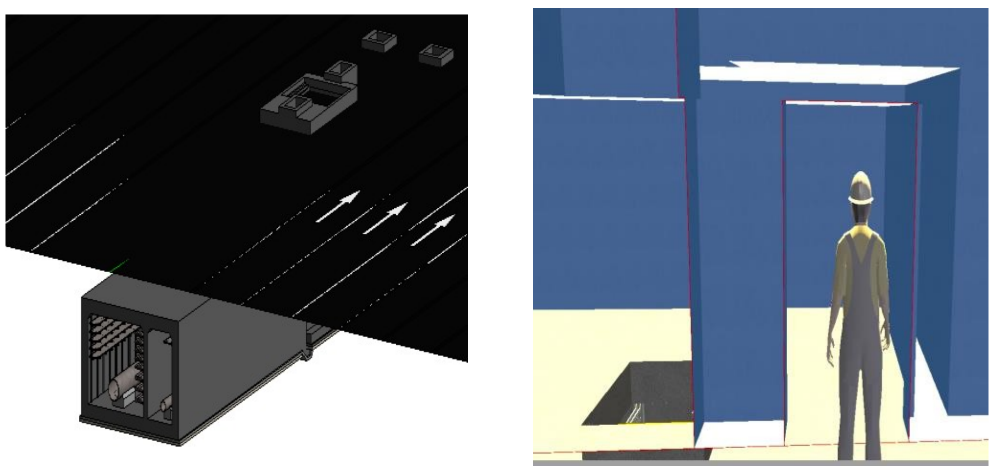


(a) Pipeline support and hangers (b) standpipe position

Figure 1. Pipeline support and hangers and standpipe.

Air vents and other openings height adjustment and check.

After modeling the openings sections with unclear details using the vertical elevations provided in the design drawings, it was observed that some of the openings sections were below the road level hence they were raised in the BIM 3D model see Figure 2(a). Through virtual wandering, the escape hatches clearance height was checked to ensure its sufficiency see Figure 2(b). Moreover, with the use of BIM the increase in quantity can be calculated accurately compared to conventional method and the negotiations for the increase in price can be made.

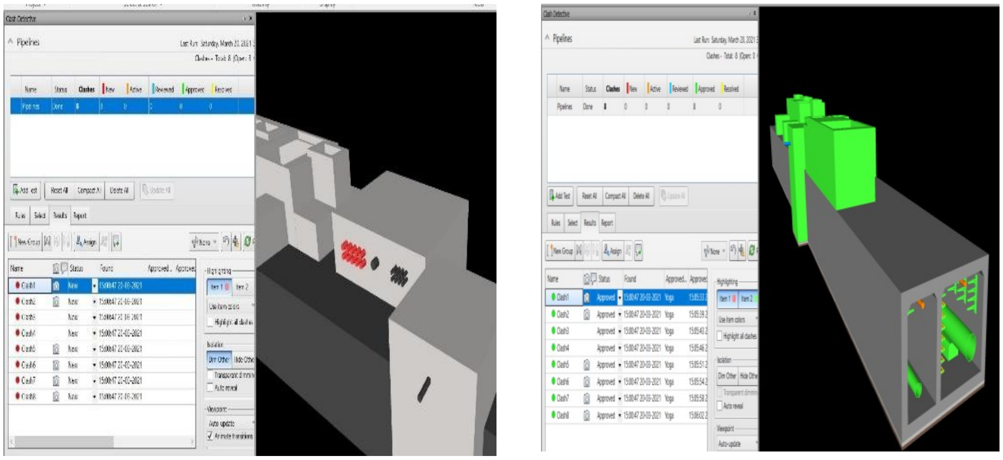


(a) Raised openings (b) Openings clearance height check

Figure 2. Adjustement and checking of openings height.

Clash detection.

In a comprehensive pipe gallery, the use of BIM for collision detection has many advantages. A section of the comprehensive pipe gallery model created from Revit was imported to Navisworks for clash detection. The clash detection function in BIM can precisely give a location of the collision points in the entire model for adjustment of the pipelines and other components. As shown in Figure 3(a), Navisworks software conducted the clash detection of the entire comprehensive pipe gallery section and accurately located the collision points. By clicking on the clash number, adjustments were made on the specific collision point. Figure 3(b) shows the adjusted collision point model.



(a) Clash detection (b) Adjusted clash points

Figure 3. Navisworks clash detection and adjustment.

Installation schedule simulation.

The simulation function in BIM gives the simulated construction process of the facility according to the schedule input values. As shown in Figure 4, the construction schedule of the comprehensive pipe gallery from foundation to the openings and pipe installation was input in the Navisworks software timeliner then simulated to visualize the construction process of the pipe gallery and the pipelines in 3D. The ability to view the construction process in 3D enables better communication and coordination between the respective departments and hence eliminates rework, delays, and cost overruns in the project.

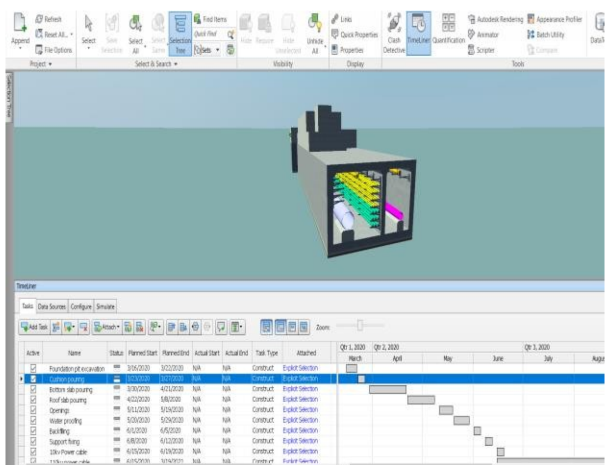


Figure 4. Construction schedule simulation.

4. Conclusion.

By applying BIM in the construction phase of a comprehensive pipe gallery, the following conclusion can be drawn:

1) The application of BIM technology in the construction phase of the comprehensive pipe gallery ensures that there is no information conflict from the traditional design mode, improves the design information, improves communication and coordination among the respective departments, and enables clash detection, saves time and cost of the project. Furthermore, the ability to carry out visual technical disclosure provides a guarantee of the construction quality of the comprehensive pipe gallery.
2) The application of BIM technology in the construction of comprehensive pipe gallery improves transparency and enable smooth negotiations between the stakeholders. Moreover, the BIM model can be provided to the operation and maintenance unit for improvement of the maintenance level since the model provides reference and technical information of the comprehensive pipe gallery components, and can also be used for facility management.

Acknowledgments

The authors are very grateful to the project manager's office of the China Railway Sixth Bureau company for their time, effort and knowledge on BIM technology and construction of the comprehensive pipe gallery.

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