Refinement construction simulation research of BIM technology on pumping concrete

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Abstract. With the gradual increase of pumping construction of medium and high-rise buildings in China, the construction requirements for concrete pumping process are gradually improved. Based on a project in Wuhan, this paper applied BIM technology on the pumping concrete construction process. Through the use of several softwares, the optimization of pumping pipeline layout, simulation of construction schedule, and priority grouping of marked bends was achieved. The details of the concrete construction of concrete pumping using BIM technology were shown, providing a reference for the application of BIM technology in the field of pumping concrete.

1. Introduction

The BIM is abbreviation of Building Information Modeling, which was first proposed by Chuck Eastman in the last 20th century. It set the foundation of the current “Building Information Modeling” for the concept of Chuck Eastman’s “Building Description System” [1]. At the same time, other scholars Jerry Laiserin [2] and McGraw-Hill Building Information Company[3] also defined the BIM concept. BIM was a Shared knowledge resource which contained digital representations of all physical and functional characteristics throughout the entire life cycle of a construction project. Furthermore, the BIM was usually used to provide a reliable basis for decision-making through the lifecycle from concept to dismantling. At the same time, during different stages and periods of the project, various stakeholders involved in the project could store, extract, transfer and modify information through BIM at any stages of the project, so as to support and map the collaborative work and the interaction between different participants and responsibilities more quickly and conveniently.

From the top on, we could see that BIM covered the integration, sharing and transmission of the whole life cycle information and achieved the purpose of fine management and macro management through the dynamic monitoring platform.

The development of BIM technology is nearly 40 years. In early 2007, the American Academy of Building Sciences introduced the relatively BIM completed standard NBIMS (National Building Information Modeling Standard), which clearly stated the connotation of BIM [4,5]. In the United Kingdom, the application of BIM technology began in 2010. The standard NBS (National Building Specification), as a Government Construction Strategy document, proposed that the collaborative 3D-BIM should be finished fully by 2016, and the whole of information documents should be managed and the goal of different stage needed to complete was formulated [6]. Subsequently, a lot of BIM technology research in different fields have been conducted by a large number of domestic and foreign scholars. Li [7] studied the way to create building model components using BIM technology in...
traditional residential design methods. Yan [8] analyzed the advantages of introducing BIM technology from the perspective of life cycle, combining with the application of BIM technology in Shanghai's actual fabricated buildings. Kang et al [9] studied the network-based BIM-4D construction visualization technology and found that the asynchronous communication method through the network can greatly improve the decision-making effectiveness and optimize data management among project participants.

In recent years, BIM technology has been gradually promoted and applied in China's civil engineering design and construction fields. For example, the application of BIM technology in projects such as China-Zun, the Metro in Guangzhou and the East Station in Hangzhou, have greatly reflected the BIM technology needs in the domestic market. However, there were few cases that the BIM technology was taken advantage to solve the construction problems of concrete in the pumping process with the purpose of refining construction,

In response to the above problems, relied on a building in Wuhan, China, this paper conducted the research as follows:

- Three-dimensional visual modeling of a floor and pumping pipes components in Wuhan was completed utilizing BIM technology.
- Adopt Project software to realize construction organization planning; import the formed documents and the 3D model in the first step into Navisworks [9,10] software, finish simulating pumping construction progress, optimize pump tube pipeline simulation and group-marking bending tube.

A scheme of applying BIM technology in this paper is shown in figure 1.

![Figure 1. A scheme of BIM application.](image)

2. Project overview

The location of a certain building is in Wuchang zone, Wuhan, China. Because the underground soil layer is soft soil, the pile foundation structure was adopted, and the upper building style of structure adopted the reinforced concrete frame structure. The construction method of the floor concrete utilized the transport-form of pumping concrete by high-pressure pumps. The pump tube was iron steel pipe with inner diameter of 150 mm, the horizontal part and the vertical part of the pump tubes were both 2 m, and the curvature at the elbow was 1/30 of the diameter of the pump tubes. The fixed base was a support form fixed by wrapping the pump tubes. The number of layers to floor body was 11, the pumping concrete was made of C60 type concrete, the column size was 600×600 (mm²), the beam size was 400×800 (mm²), and the connection diagram of pumping truck and pumping tube is shown in figure 2 below.
3. Establishment of 3D model and optimization of pump tube layout

This paper chose Revit included in series of BIM softwares to carry out three-dimensional visual modeling of the main structure and pumping pipeline system of some specific project for a building in Wuhan. The 3D visualization model established by Revit software can visually and clearly display the dimensional relationship, positional relationship, apparent material of every components, and virtually and realistically express the specific objects in the real scene. For example, in this paper, the connection joints and support component sets of pumping pipes are shown below (figures 2 and 3), created by the way of self-creation “family” library and created according to the size of the real connecting and supporting components where truly reflecting the specific position of joint and support of the pumping pipes, providing the basis for the optimization of the pumping piping arrangement.

According to the actual project, the spatial position of structural sets created in Revit family via the self-built family and the system family function in 3D space was usually modified by software instructions such as move, offset, alignment, mirror, copy, rotate and construct under modify- button in the elevation and the grid system. Firstly, the three-dimensional modeling of the pump piping system was completed, and different construction material stacking positions and driving routes were divided in the site model. The on-site pumping layout model was rationally designed and optimized, thereby reducing the numbers of bending of the pumping pipelines and the total length of the pumping pipes with achieving the purpose of using BIM technology to reduce pumping pressure loss, civilized operation and fine construction.

The data before and after the optimization of the number and length of the horizontal pump tubes on the ground are listed in table 1.
Table 1. The data of pumping tubes in horizontal layout.

| Category      | Numbers of straight pipes | Numbers of bend pipes | Numbers of joint pipes | Straight pipes length /m | Total length of pump lines /m |
|---------------|---------------------------|-----------------------|------------------------|--------------------------|-------------------------------|
| Unoptimized   | 35                        | 6                     | 41                     | 67                       | 74.85                         |
| BIM-layout    | 31                        | 4                     | 35                     | 59                       | 65.28                         |

The article completed the creation of basic structures’ component such as walls, beams, slabs, columns, piles and pile caps, furthermore completed the construction of this building in Wuhan, including the doors, windows, roofs, slabs, stairs, railings, curtain walls and so on. The finally Revit model of 3D visualization is shown in figure 4. In the figure, the different enclosed areas indicate different stacking positions of types of construction materials, the dark circles on the outer ring indicate the driving route, and the light bars in the inner circle indicate the routes in the construction. The establishment of 3D visualization model provided the necessary foundation for realizing construction progress simulation of the next step work.

![Figure 4. Revit model of body and pump tubes system.](image)

4. 3D visualization of construction progress simulation and priority marking
The 3D visualization construction progress simulation is also called BIM-4D modeling information technology in the BIM field. It is a dynamic correlation between the 3D visualization construction model and the schedule of project constructions using a series of BIM softwares, which provides help for the pre-project and construction of the project. And also it provides supporting data timely and accurately about the ordering, distribution and utilization of materials in the process with improving engineering efficiency.

This paper adopts Microsopject2010 as a construction process programming software in BIM softwares to compile and optimize the construction schedule. This software is developed by Microsoft to assist project managers in developing plans, scheduling and task allocation. It can efficiently track project progress, manage engineering budget and calculate the size of the engineering quantity. Using the Project2010 software, the different components in the Revit 3D visualization model were hierarchically organized into names and serial numbers in order of categories and time completion. Then the theoretical and actual start time and completion time of each component of the created model in the software were input, according to the rules and orders of preparation, which was determined in advance and the specific arrangement process of the engineering project time. Through the divided construction task also named Work Breakdown Structure (WBS), the paper created a different level of
construction schedule, as shown in figure 5 below. The mpp formal document created by Microsoproject provided the basis for the completion of the next 3D visualization construction progress simulation.

As a simulation software in the BIM softwares, AutodeskNavisworks is a building engineering management software developed by Autodesk, with which engineers usually optimize structural and architectural design and control the quality of construction projects. This article imported the two things into Autodesk Navisworks, one was the rvt formal model created by Revit and the other was the mpp formal document created by Microsoproject. Through the “select tree” and viewpoint function of Navisworks software, it was conveniently to save the 3D model created by Revit according to certain rules. Then, by using different colors for different floors and functional components, the simulation growth problems in the model can be clearly observed so that the designer can timely modify and optimize the structural design to avoid unnecessary waste. Figure 6 below is a simulation diagram of column hierarchical displayed by nw software. The column of each layer of color represents the columns of different layers. It was more convenient to find out whether the numbers and position of components in the simulation construction process were correct through the simulation of different components, thereby achieving a refined simulation construction process.

As to the concrete transportation and pouring operation, it was carried out continuously in the pumping process. With the three-dimensional visual construction progress simulation implemented, the three things could be found in advance, that was problems in the construction process, the construction machinery arrival sequence and the construction progress. Thus, it could meet the needs of the project party to accurately grasp the construction situation during the construction process at
any time. In this paper, the Timeliner function in Navisworks software was used to simulate the 3D visualization construction progress. The resulting effect is shown in figure 7. Using NW software, not only realized the simulation of construction progress, but also reproduced the progress of the project according to the requirements of the construction process at any time. This three-dimensional visual construction simulation was corresponded to the actual construction progress node, which greatly facilitated the engineer to compare the construction progress of the site with the progress of Navisworks 4D model so as to find the deviation of the construction process, arrange the construction personnel and determine the order of the construction machinery.

At the same time, for the pumping elbows in the pumping system, priority grouping were performed in a manner similar to that of figure 6, depending on the phenomenon of trapping of the elbow during the pumping process. Level1: Horizontal and vertical conversion elbows > Level2: Top elbows > Level3: Horizontal elbows. With the help of the grouping function of the software, when pumping problem occurs, the construction workers could use the priority order of the marking to conduct the inspection, which makes the construction process simpler and clearer, with achieving the purpose of using the BIM technology to realize the fine construction of the pumping process and improving the construction efficiency in pumping construction.

5. Conclusion
- In this paper, we optimized the arrangement of the pumping pipeline by revit three-dimensional modeling, reducing the length of the overall pumping pipeline, thus reducing the pressure loss during pumping.
- Through detailed demonstration of the refinement simulation construction process using revit, project and nw software, the problems of construction works' arrangement, mechanical approach sequence and so on were solved with improving the efficiency of pumping construction by BIM technology.
- The BIM technology was used to model, prioritize and mark the pumping elbows, which provided a reference for field personnel to check the pumping and blocking problems in order with the efficiency of the pumping process improved.

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