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Application Research of BIM in the Construction Phase

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Abstract. Combined with various practical project cases, this paper systematically studies the practical achievements and development trends of the basic applications, innovative applications, and "BIM+" integrated applications of Building Information Modeling (BIM) technology in the construction phase. It clarifies the core value of BIM technology for construction enterprises in improving management efficiency, reducing costs, and ensuring quality and safety, provides technical application references for industry practitioners, and contributes to promoting the in-depth implementation and innovative development of BIM technology in the field of building construction.

Keywords: BIM Technology; Construction Phase; Collaborative Application.

1. Introduction

At present, the construction phase of the construction industry faces challenges such as complex project management, frequent design changes, high pressure on cost control, and strict requirements for quality and safety. The traditional management model can hardly meet the needs of high efficiency and precision for modern construction projects. As a core platform for digital information integration, BIM technology constructs a 3D information database to integrate information from all phases of the project's whole life cycle, realizing real-time data sharing and collaborative work, and thus providing an innovative approach to solve construction problems. In recent years, BIM technology has been widely applied in large-scale construction projects at home and abroad, demonstrating significant advantages and becoming a key driving force for the digital transformation of the construction industry. This paper conducts a comprehensive and in-depth study on the application of BIM in the construction phase to provide references for industry practice.

2. Application Research of BIM in the Construction Phase

2.1. Basic Applications of BIM in the Construction Phase

2.1.1. Construction Model Deepening

The deepening of the construction model is a core basic application of BIM technology in the construction phase. Based on the BIM model delivered in the design phase, the construction team conducts refined improvement on the professional models of architecture, structure, and MEP (Mechanical, Electrical, and Plumbing) in accordance with construction techniques, material characteristics, and on-site actual conditions. Taking the Asian Infrastructure Investment Bank project as an example, the BIM model during the detailed design phase clearly presents the spatial relationship between the steel bars in the core tube area and the steel structure embedded parts. Construction personnel can accurately grasp the component dimensions, installation sequence, and connection methods through the model, which directly reduces rework caused by missing or deviated drawing information, lowers material waste, and improves construction efficiency by approximately 15%. Meanwhile, the use of the BIM model for net height inspection can promptly identify areas that do not meet the functional requirements and feed back to the design unit for optimization solutions, ensuring that the construction matches the actual needs [1].

2.1.2. Optimization of Construction Site Layout

Scientific construction site layout is crucial for ensuring the efficient and orderly progress of construction. Relying on the 3D modeling and simulation analysis functions of BIM technology, accurate modeling and multiple rounds of simulation verification can be carried out for on-site road planning, material storage area settings, and parking positions of large equipment such as tower cranes (Figure 1). Taking the Hangzhou West Railway Station project as an example, during the early construction stage, BIM software was used to simulate the operating radius of tower cranes and the material transportation routes. After optimizing the site traffic organization, not only the secondary transportation of materials was avoided, but also the risk of mechanical collisions was significantly reduced. The site utilization rate was increased by 20%, and the construction period was indirectly shortened by approximately 10 days [2].

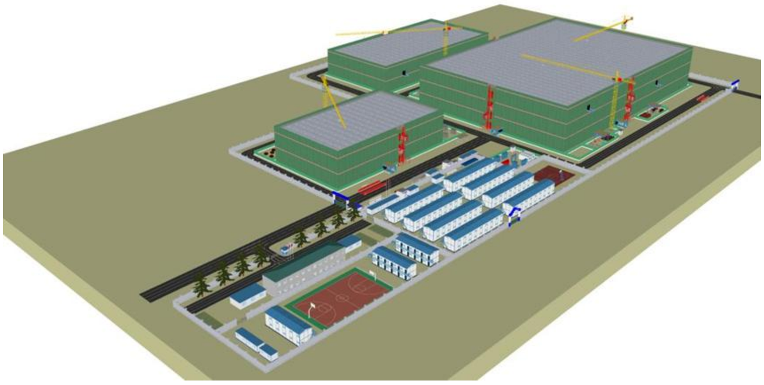

Figure 1. Construction Site Layout

2.1.3. Collision Detection and Pipeline Integration

In traditional construction, the drawings of various disciplines are prepared by different teams, and insufficient collaboration easily leads to drawing conflicts such as pipeline crossings and component interferences. Such problems are often exposed during on-site construction, and rectification requires a lot of manpower, material resources, and time, which may also affect project quality. By integrating multi-disciplinary models such as civil engineering, MEP, and curtain walls, BIM technology constructs a complete 3D information model. Using the software's collision detection function (Figure 2), spatial conflicts in various professional models can be automatically identified before construction, and a detailed report can be generated. In a high-rise building project, collision detection was carried out using the BIM model, successfully identifying the spatial conflict points between the air ducts and the structural beams. After engineers adjusted the pipeline routing according to the report, the rework rate of on-site pipeline installation was reduced by more than 30% [3].

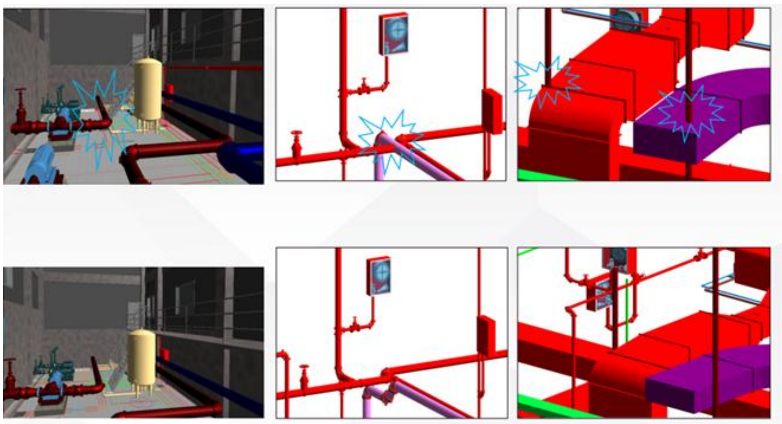

Figure 2. Application of BIM in Collision Detection

2.2. Innovative Applications of BIM in the Construction Phase

2.2.1. Virtual Construction and Schedule Simulation

Virtual construction technology based on the BIM model is an important innovative application in the construction phase. This technology deeply associates the construction schedule plan with the 3D BIM model, constructing a 4D (3D model + time dimension) schedule simulation system. It can dynamically and intuitively display the content of each construction phase, facilitating project managers to grasp the progress in real time and promptly identify deviations (Figure 3). In the Hangzhou West Railway Station project, BIM technology was used to simulate the steel structure hoisting sequence and concrete pouring process. Potential problems in the connection of key processes were identified in advance, and optimization measures were formulated, which improved the accuracy of the total project duration control to ±3 days. In addition, virtual construction technology can also provide visual technical disclosure for the construction of complex nodes such as long-span roof installation. By experiencing the virtual scene in an immersive manner, construction personnel can more intuitively understand complex processes and technical requirements, reducing the difficulty of drawing comprehension and improving construction quality and efficiency [2].

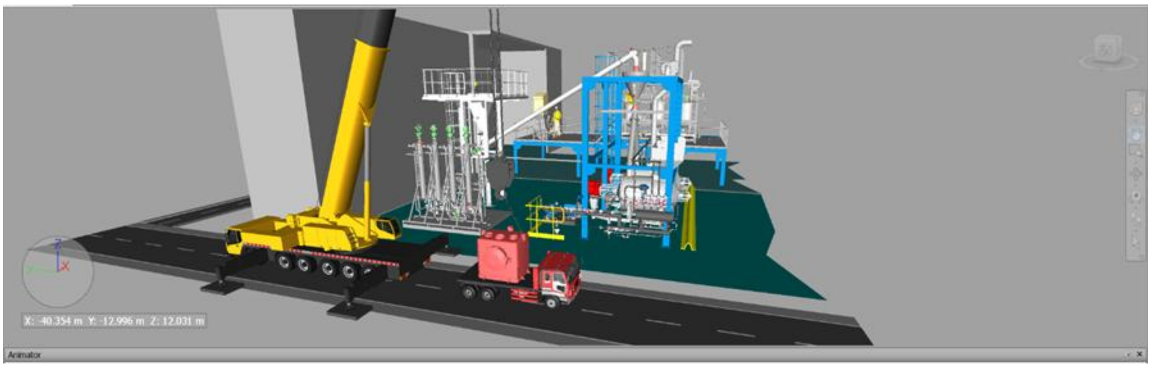

Figure 3. Virtual Construction Simulation of BIM Model

2.3. "BIM+" Applications in the Construction Phase

2.3.1. BIM+5D Integrated Management

The BIM+5D technology integrates the time (schedule) and cost dimensions on the basis of the traditional 3D spatial model, constructing a five-dimensional comprehensive management platform. Taking a residential project as an example, based on the BIM5D platform, the construction schedule plan is closely linked to the cost budget. During the construction process, the platform dynamically counts the actual cost consumption corresponding to the completed project quantity and compares it with the budget cost. If there is a risk of overspending, the system issues a timely early warning to remind managers to take control measures. Through real-time monitoring of cost deviations in sub-projects, the accuracy of the total cost control of the project is improved to ±5%, effectively avoiding the overspending problem caused by delayed data in traditional cost accounting [4]. In addition, the BIM5D model can also simulate the cost changes under different schedule plans, providing quantitative basis for construction decisions and helping to achieve the optimal balance between cost and schedule.

2.3.2. BIM+VR/AR Visual Technical Disclosure

The integration of BIM (Building Information Modeling) with VR (Virtual Reality) and AR (Augmented Reality) technologies has brought revolutionary changes to construction technical disclosure. Before the construction of complex joints, construction workers can wear VR devices to "immerse themselves" in the virtual scene built by the BIM model. They can observe the component installation process from multiple perspectives and with detailed views, intuitively grasp the process requirements and operation procedures, which significantly improves the accuracy of understanding complex technologies (Fig. 4).

In scenarios such as highway construction, BIM + VR technology also plays an important role. The construction team uses this technology to conduct virtual construction rehearsals, experience every detail of the construction in advance, and identify potential construction risks and technical difficulties—for example, planning the hoisting path of large - scale equipment to ensure construction safety. At the same time, training and drills in the VR environment can improve the operational skills and safety awareness of construction workers, thereby reducing the occurrence of actual construction accidents [6].

AR technology overlays BIM model information with the real - scene of the construction site to provide intuitive guidance for construction workers. For instance, wearing AR glasses enables workers to directly view information such as the position and size of embedded parts in the model, which assists in accurate positioning and operation, and enhances construction quality and efficiency.

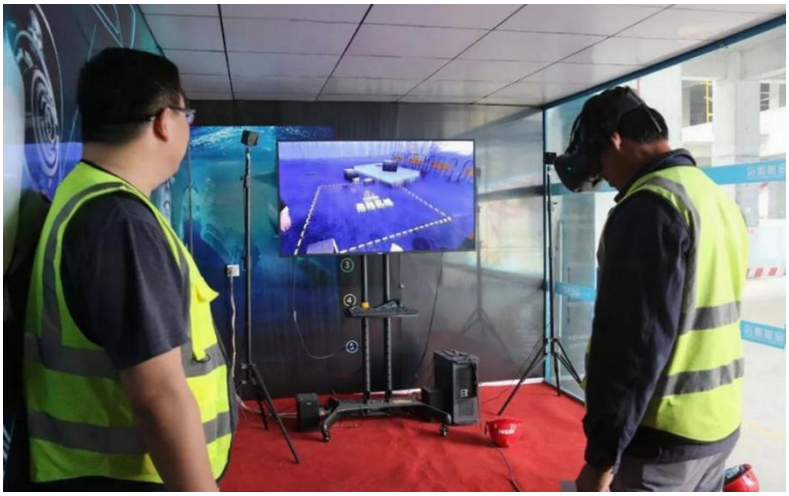

Figure 4. Interactive Integration of BIM and VR

2.3.3. BIM+GIS Real-Time Monitoring

The in-depth integration of BIM (Building Information Modeling) and GIS (Geographic Information System) technologies enables comprehensive management of both macro construction scenarios and micro details (Fig. 5). GIS technology is responsible for processing project spatial environment data, which can integrate the layout of utility tunnel projects and surrounding buildings, environmental parameters, traffic conditions, and climate information to plan the optimal routes from procurement and logistics to construction; in highway projects, GIS technology can combine with BIM models to simulate traffic flow and structural stress, predict and prevent potential problems, and improve facility safety and service life [6]. BIM technology focuses on the analysis of internal building data and conducts integrated management and control by combining information such as schedule and cost. The two technologies rely on the same data processing engine for project management, meeting the data transmission and collaboration needs in the construction of projects such as road and bridge projects and underground utility tunnels [5].

During the construction of urban underground utility tunnels, GIS technology can be used to efficiently integrate and monitor the layout of utility tunnel projects and surrounding building facilities, environmental data, road traffic, and climate conditions, determine the optimal routes from procurement to logistics to construction, update inventory information, track the status of material transportation, and achieve comprehensive real-time control of transportation costs; at the same time, it arranges the schedule management of construction projects and truly reflects the geographical data of the construction site. BIM technology, on the other hand, can combine various risk factors such as schedule, cost, quality, and safety with multi-dimensional building information models to conduct comprehensive integrated management and control. In addition, by using professional software to analyze the slope direction of underground terrain, combining the BIM + GIS system to model the proposed utility tunnel, and conducting visible area analysis, the terrain and environmental characteristics can be checked at any time, the travel path can be planned, the visible area analysis results can be dynamically rendered, the possibility of disasters such as high ground stress and high-pressure groundwater can be estimated, the suitable construction area can be accurately located, and the underground space construction land can be rationally used, so as to protect water and soil resources and reduce the risk of irrational land use [7].

Figure 5. Effect of BIM+GIS Integration

3. Conclusion

The application of BIM technology in the construction phase has gradually expanded from basic functions to innovative applications and integrated applications with emerging technologies. Its core value is reflected in three aspects: Firstly, it realizes the high integration and sharing of project information through digital models, reducing information transmission errors and rework costs. Secondly, it improves the intuitiveness and predictability of construction by means of visualization and simulation technologies, enhancing construction accuracy and safety. Thirdly, it breaks down the information barriers among various project participants, realizing efficient information communication and collaborative work, and improving project management efficiency.

Looking forward to the future, with the in-depth integration of cutting-edge technologies such as Artificial Intelligence (AI) and big data with BIM, its application will focus more on the field of "intelligent decision-making". When promoting the application of BIM technology, it is necessary to combine the actual needs and characteristics of the project, avoid blind investment, ensure that it fully exerts its digital empowerment role, and provide support for the high-quality development of the construction industry.

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