Research on construction quality control of prefabricated concrete bridge based on BIM technology

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Abstract: In recent years, China has made great efforts to promote prefabricated concrete bridge technology. However, due to the construction quality problems, the application of prefabricated concrete bridge technology is limited. BIM technology can be applied to the whole life cycle of a construction project, which is a new way to solve the problem. This paper uses questionnaires to investigate the quality problems of prefabricated concrete structures, the necessity of BIM application at various stages and the application effects are analyzed. The results show that the application of BIM Technology in each stage of the project can improve some quality problems.

1. Introduction
BIM (Building Information Modeling) technology uses three-dimensional digital technology as the technical foundation to integrate various relevant information in the engineering project. It is also a digital technology applied to design, construction and management[1]. BIM technology can be applied to the whole life cycle of a project: (1) establishing a three-dimensional digital information model in the design stage; (2) establishing a progress model required by the project in the construction stage[2]; (3) simulation of construction methods and shape of finished products in the final acceptance stage. Meanwhile, the information after acceptance can also be compared with the as-built model. In the operation and maintenance stage, the project operation and maintenance platform are also established through BIM technology to realize remote monitoring, and data analyzing[3].

Prefabricated concrete bridge refers to the bridge assembled by precast concrete components produced in the factory. It has the advantages of simple installation, integrity and good seismic resistance[4]. The key technology of prefabricated bridges lies on the factory, standardized and intelligent production of prefabricated components; the convenient and reliable connection of on-site splicing nodes; the lightweight, automation and future intelligent installation equipment of prefabricated components[5]. As for the problems occurred in application, BIM technology provides new solutions, which are mainly manifested in the following aspects[6]: creating component library to improve the modeling efficiency; 4D process simulation to improve the accuracy of site construction; quality management system, analysis of problem components. There are many types of prefabricated components with complicated connecting parts. The digital information model of BIM can avoid misconnects of various parties. BIM technology can also update the model in real time according to
the progress of the site, and reflect the quality status and existing problems. At the same time, some quality problems can be avoided through analysis, which simplifies the dynamic quality control.

At present, the quality management of prefabricated concrete structures has increased from the traditional single-mode site management to the coordinated management between factories and construction sites \[7\]. This change makes the quality management of prefabricated concrete structure become a hot issue in the industry. How to apply BIM technology to the quality control of prefabricated concrete bridge has been a subject worthy of studying.

2. Questionnaire survey
The objects of the questionnaire survey include consulting units, owners, construction units, supervision units and professional counterpart college students. The subjects of the questionnaire are familiar with prefabricated concrete structure and BIM Technology. A total of 106 questionnaires are collected, including 88 valid questionnaires. The data of the survey results are analyzed by SPSS software. The Cronbach α coefficient of this questionnaire is 0.91, which is greater than 0.9, indicating that the reliability is high. The validity of the data of the survey results is also analyzed. The KMO value is 0.851, which is higher than 0.8, indicating that the collected data is in good validity. Analytic hierarchy process (AHP) is used to analyze the data obtained from the questionnaire, as shown in table 1-table 5.

| Item                                                                 | Feature vector | Weights     | Maximum eigenvalue | CI     |
|----------------------------------------------------------------------|----------------|-------------|--------------------|--------|
| Lack of technical personnel; high requirements for construction labors, leading to poor construction quality. | 0.986          | 12.321%     |                    |        |
| Inadequate management of finished components may cause quality problems, such as component cracks and exposed ribs. | 1.014          | 12.679%     |                    |        |
| Large-scale components are inconvenient in the transportation process, which may cause damage or internal steel rebar displacement of prefabricated concrete components. | 0.976          | 12.201%     |                    |        |
| The design description is not detailed or contradictory.             | 1.024          | 12.799%     |                    |        |
| The accuracy of lifting equipment is not high, which may cause the splicing accuracy of component joints not up to the standard. | 1.053          | 13.158%     | 8.000              | 0.000  |
| In the process of precast component connection, the grouting process does not meet the requirements or sleeve deviation, which may cause the overall quality problems. | 0.938          | 11.722%     |                    |        |
| In the construction, the location of steel rebars is different from the traditional way, which makes it easy to have problems in reinforcement overlapping and thickness of concrete cover. | 0.976          | 12.201%     |                    |        |
| The joints between the prefabricated components are not smooth, which easily leads to deviations in installation dimensions. | 1.033          | 12.919%     |                    |        |
Table 2 AHP analysis results of BIM application necessity in design stage

| Item                        | Feature vector | Weights   | Maximum eigenvalue | CI  |
|-----------------------------|----------------|-----------|--------------------|-----|
| Spatial planning            | 1.138          | 18.968%   | 6.000              | 0.00|
| Collision detection         | 0.879          | 14.642%   |                     |     |
| Component design            | 0.978          | 16.306%   |                     |     |
| Establishment of component library | 0.948     | 15.807%   |                     |     |
| Construction site simulation| 1.008          | 16.805%   |                     |     |
| Engineering quantity statistics | 1.048         | 17.471%   |                     |     |

Table 3 AHP analysis results of BIM application necessity in production and transportation stage

| Item                        | Feature vector | Weights   | Maximum eigenvalue | CI  |
|-----------------------------|----------------|-----------|--------------------|-----|
| Component automated production | 0.998        | 16.639%   | 6.000              | 0.00|
| Plant stacking plan         | 0.958          | 15.966%   |                     |     |
| Automatic tracking          | 0.968          | 16.134%   |                     |     |
| Transportation route planning | 1.008        | 16.807%   |                     |     |
| Component transportation tracking | 1.039     | 17.311%   |                     |     |
| Component delivery management | 1.029        | 17.143%   |                     |     |

Table 4 results of AHP analysis on the necessity of BIM application in construction stage

| Item                        | Feature vector | Weights   | Maximum eigenvalue | CI  |
|-----------------------------|----------------|-----------|--------------------|-----|
| On-site component stacking planning | 1.036        | 20.727%   | 5.000              | 0.00|
| Cost management             | 1.009          | 20.182%   |                     |     |
| Schedule management         | 1.027          | 20.545%   |                     |     |
| Quality management          | 0.945          | 18.909%   |                     |     |
| Security management         | 0.982          | 19.636%   |                     |     |

Table 5 AHP results of BIM application effect in different stages

| Item                                                                 | Feature vector | Weights   | Maximum eigenvalue | CI  |
|---------------------------------------------------------------------|----------------|-----------|--------------------|-----|
| BIM technology can pre-construct complex construction nodes, such as using visibility to observe the overlap of internal steel bars before grouting sleeves are connected. | 1.072          | 21.443%   |                    |     |
| BIM Technology is used to detect the collision between the models, and the collision problems between steel rebars and walls can be found during the construction. | 0.969          | 19.381%   |                    |     |
| Using BIM technology for parametric modeling can improve work efficiency. | 1.021          | 20.412%   | 5.000              | 0.00|
| BIM technology is convenient for the management and acquisition of production information of prefabricated components in the factory. Combined with Internet of Things (IoT), BIM can track the components after delivery, and enhance the traceability of information. | 0.979          | 19.588%   |                    |     |
| BIM Technology provides an information sharing platform, which helps to share relevant information in the management process and control the quality at all times. | 0.959          | 19.175%   |                    |     |

3. Results and discussion
Among the common problems of prefabricated concrete bridges, the component splicing accuracy caused by the low precision of lifting equipment is the most serious; the rework problem caused by the
lack of detailed expression of design drawings ranks the second, the improper management of finished components and the technical level of construction personnel are ranked in the third and fourth places respectively. The transportation of other components and the connection problems between components also affect the quality of prefabricated concrete bridge to a certain extent. In order to improve the quality of prefabricated concrete bridge, the engineering and technical personnel can start to consider eliminating the traditional 2D drawings, using 3D model to express, using information technology to pre-assemble the construction process, determining the appropriate construction machinery and technology, and strengthening the technical level of construction personnel.

In the design stage, BIM technology is considered to be the most necessary for spatial planning, which have the greatest impact and followed by quantity statistics. The construction site simulation and component design are in the third and fourth places respectively. For the prefabricated concrete bridge construction site, the installation sequence of components should be considered after the components are delivered from the factory, so as to avoid the damage of components caused by improper placement in the scheduling. The application of information technology in the field of engineering quantity statistics is helpful for timely statistics of engineering quantity.

In the stage of component production and transportation, the management and tracking of components after leaving the factory have the greatest impact on the quality of components. It is necessary to introduce BIM technology to assist component management. The route planning of transportation and the automatic production of components are in the third and fourth places respectively. Radio frequency identification (RFID) technology can be introduced to track the components in real time and feedback the transportation situation. Since there are many uncertain factors in the transportation process, it is necessary to record the component status in time to facilitate the determination of responsibility.

In the construction stage, BIM technology is considered to be the most necessary to improve the site component stacking planning, followed by cost and schedule management. Moreover, safety and quality are in the fourth and fifth place respectively. In the field of component stacking planning, the engineering and technical personnel need to consider the size of each component, stacking rules, construction sequence, etc., which greatly affects the quality of components.

As the effect of BIM technology to improve the quality of prefabricated concrete bridge, BIM technology can be used for pre-construction of complex construction nodes. The internal influence of visibility observation is the most important, followed by the parametric modeling of BIM. The joint connection problem of prefabricated concrete bridge is also important, which affects the integrity and safety of the whole structure. Considering the introduction of information technology, the problem can be improved to a certain extent. Meanwhile, parametric modeling affects the efficiency and quality of component modeling.

4. Conclusions
(1) The most frequently existing problems of prefabricated concrete bridge are the construction quality and technical problems. The addition of BIM technology can improve the design and construction problems of components.

(2) In the stage of engineering design, BIM can establish component library and component standard, and deepen the design of component is conducive to improve the accuracy. In the stage of engineering production and transportation, due to the sharing of information, it is convenient to trace the situation of components, determine the source of responsibility, optimize the transportation routes, and reduce the damage of components in the process of transportation. In the construction stage, BIM technology helps to optimize the scheme of node connection, optimize the layout of reinforcement, and optimize the stacking of components in the field, thus facilitating the construction process.

Acknowledgements
The authors wish to acknowledge the financial support of “Ningbo public welfare science and technology project (Grant No. 202002N3121)”.
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