Research on BIM and virtual pre-assembly technology in construction management

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ABSTRACT: In the field of architecture, the virtual pre-assembly of prefabricated components (steel structure, some of concrete structure) need to obtain data through 3D laser scanning or other instruments, and then realize by computer virtual imitation. In recent years, the combination of BIM and virtual pre-assembly is more and more used in some large and complex steel structures, especially in the application of technology, and the effect is good. However, for the combination of BIM and virtual pre-assembly, there is little research on management. In this paper, the combination of BIM and virtual pre-assembly in the management of the application of a more in-depth study. Compared with the traditional construction management, the combination of BIM and virtual pre-assembly optimizes the key construction steps such as construction preparation, quality inspection, schedule management, resource coordination, etc., which can serve the whole life cycle of the project. We have applied the combination of BIM and virtual pre-assembly to the construction management of a large complex steel structure. The results show that the integration of BIM and virtual pre-assembly technology has many advantages over the traditional construction management. It can find some problems that traditional management can't find in advance, and allocate resources reasonably.

1 INSTRUCTION

Construction project management defined by Ding Zhang et al.(2011)is the fundamental to ensure the construction progress, project quality and safety construction. The traditional management mainly depends on the rich experience of managers, while the arrangement of materials, labor and general equipment depends on the well prepared construction organization design. Woonseong et al.(2016)proposed a simulation framework integrating building information model (BIM) to predict the productivity dynamics during the construction planning stage. To develop this framework, the researchers examined key factors that affect operational level productivity and then predicted productivity dynamics. Chen et al.(2014) discussed the advantages, organization and process (POP) data definition structure of 4D BIM in high-quality application based on construction specifications by building models in products, and verified it with the construction stage of Wuhan International Expo Center as an example. The efficiency and quality of construction can be guaranteed if the site construction meets the construction organization design. When the site construction situation does not conform to the construction organization design and the situation is not serious, the construction organization design can be modified appropriately to adapt to the actual situation. However, when the actual situation of the site is seriously inconsistent with the construction organization design,the managers have to take a lot of remedial measures, or even rework.

Virtual construction can prevent and solve some key problems in construction management, especially for prefabricated structures ,Obonyo (2011)said. In virtual reality system, managers can know the construction results of existing structures in advance. The management personnel can optimize the preparation work according to the construction results to reduce the risk in the construction. Of course, it needs simulation results to be reliable. Through the virtual construction demonstration of the future conditions, managers can find the construction hidden dangers and safety hidden dangers in advance. Managers take corresponding measures to control in time to ensure the safety of personnel and avoid unnecessary losses. Through the relevant discussion, managers can find the deficiencies of the construction

scheme. They will revise the plan to ensure the quality of the project.

Guo et al.(2018) applied BIM system to carry out virtual pre-assembly of steel structure to improve the quality of construction. Li et al.(2019) applied BIM Technology to the construction of a large-scale anisotropic steel structure. By using the BIM model to reduce the collision and simulate the site construction, the fine construction and management of the site steel structure and curtain wall project are realized. Xu et al. (2019) used the function of BIM Technology visualization to deepen the design of long-span truss. This method avoids collisions and ensures the construction progress on site.

Reliable and comprehensive data is the guarantee of virtual construction simulation results. The total station has been proved to be a reliable instrument. However, the total station often needs other media to locate the measured objects, such as reflectors and manual line drawing. The existence of medium has certain influence on feature acquisition. In addition, the rate of the total station limits the number of points, and the limited points have certain limitations in large and complex structures. 3D laser scanning is one of the most effective tools to measure 3D objects and structures. It can capture millions of points per second with linear accuracy in the millimeter range.

In the application of virtual pre-assembly with measuring instruments, Case et al.(2014) used the total station to assemble the bolt hole position of Chernobyl nuclear power plant protective cover project by digital simulation. The principle is the generalized procrustes analysis method proposed by researchers. Qin et al.(2019) combined the three-dimensional laser scanning technology with BIM Technology, and put forward the integrated engineering quality control methods of component processing quality inspection, virtual pre-assembly on construction site and real-time monitoring during construction for an arch bridge. Liang et al.(2018) introduced a set of virtual pre-assembly steps and methods of bolt connected bridge components, which can be used for multi-faceted splicing of steel truss beams. Liu et al.(2020) studied the virtual pre-assembly technology of steel truss beam in combination with BIM and 3D laser scanning, and virtual pre-assembly the truss under three working conditions, and achieved satisfactory results.

According to the related literature, there are few researches on BIM and virtual pre-assembly technology in construction management, which is a topic worthy of more discussion. This paper will summarize a set of technical routes about BIM and virtual pre-assembly technology in construction management, and conduct a more in-depth study on this topic through a case.

2 BIM AND VIRTUAL PRE-ASSEMBLY TECHNOLOGY IN CONSTRUCTION MANAGEMENT

Construction organization management is divided into three elements by Yang (2019): construction preparation, component inspection and progress management. BIM and virtual pre-assembly technology can be used to optimize the traditional construction management. The following is the optimized construction management workflow.

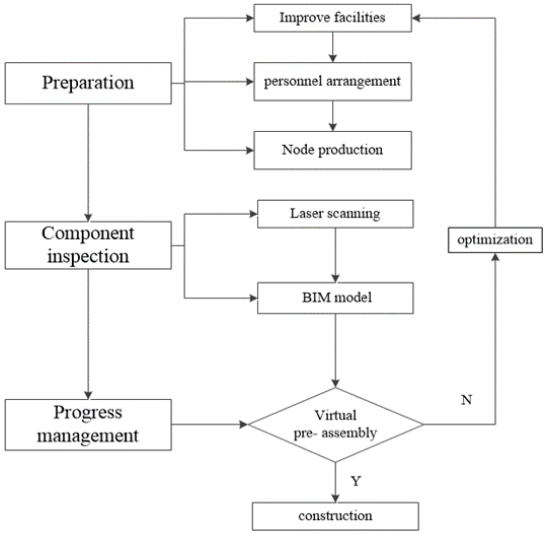


Figure 1. Optimized construction management workflow

2.1 *Preparation stage*

Improving construction facilities is one of the necessary steps before construction. In addition, managers should arrange personnel reasonably. For components, especially prefabricated structural components, nodes are the key elements of the successful construction of components, so high-quality manufacturing nodes are one of the key tasks.

2.2 *Component inspection*

2.2.1 *Data acquisition*

The prefabricated components need to be inspected, and the traditional method can use the total station to collect the limited points of components. The measurement equipment determines the data acquisition of the structure object. Among them, the data measured by the total station can't reflect the three-dimensional shape of component splicing comprehensively and intuitively, but the construction of corresponding component in collision inspection is important. The potential risk of construction only depends on the finite point simulation and predic-

tion, and the hidden danger of safety may not be reflected in time.

We used three-dimensional laser scanning and photogrammetry to detect components and obtain comprehensive and reliable information of components. It is worth noting that node is the key factor of component, and data acquisition is needed. Different 3D laser scanners have different precision, and the distance is an important factor affecting the point cloud, so we should choose the appropriate instrument according to the actual distance and other factors,Cai et al. said(2019).

2.2.2 *BIM model*

The acquired point cloud data needs to be preprocessed, including the steps of station collage, denoising and down sampling. Among them, the classic algorithms of point cloud station include ICP Gregory et al.(2002)and so on. The feature extraction of components is obtained by corresponding algorithms, such as point cloud objects with plane features can be processed by growing region algorithm (xue et al. 2008)and RANSAC(Yang et al. 2016).

The extracted feature parameters are the basis of the reverse BIM model. The common BIM software includes Revit, Tekla, Catia, etc. Among them, Revit is widely used in housing construction and other fields, Tekla is often used in the construction of steel structures, and Catia surface design is unique. We need to choose different BIM software according to our needs.

2.3 *Progress management*

2.3.1 *Construction progress prediction*

Through the virtual pre-assembly to predict the construction progress of components, only the virtual pre-assembly results meet the schedule requirements can the construction be carried out.

The goal of traditional alignment algorithm is to minimize the sum of the least squares of the difference between two matrix A and B. In order to ensure the effect of virtual pre-assembly, according to the principle of Procrustes analysis method, the two matrices to be spliced are simulated and aligned. The alignment goal of this method is the principle of minimizing the iterative change of the center of mass of two matrices, which is better than the minimization of the sum of squares of the difference between A and B matrices.

2.3.2 *Optimization preparation*

If the results of virtual pre-assembly meet the requirements of component splicing, then construction can be carried out. However, when the results of virtual pre-assembly do not meet the requirements of component splicing, managers need to optimize the preparatory work to ensure the next step of construction smoothly. Generally, nodes can be processed to meet the requirements. Such advanced optimization preparation can reduce the risk of subsequent construction and ensure the smooth progress of subsequent construction.

2.4 *Guarantee the construction progress*

The follow-up construction steps are also an important guarantee for the construction. Generally speaking, as long as the front work is completed with high quality, the follow-up construction work only needs to be carried out step by step. Of course, managers need to deal with unexpected situations.

3 CASE STUDY

3.1 *Project overview*

Chongqing Raffles air corridor is more than 200 meters away from the ground. The corridor is a steel structure which is connected at roof's from the ground to the air corridor. There are three lifting sections in total, of which the maximum weight is 1100t. According to the principle of Cartesian coordinate system, there are three possible deviations when it is combined with roof's ends, i.e. axial deviation (x direction), transverse deviation (y direction) and vertical deviation (z direction). When a deviation exceeds the limit, it will cause the closure to fail to work normally. The construction personnel have to cut high above the limit. These conditions will greatly increase the closure cycle and the risk of high altitude closure.

If the reliable inspection of components is not carried out, there are three disadvantages of this construction management method:

1) the final state of corridor splicing is unknown, resulting in the inability to accurately organize appropriate construction personnel to cut the end in advance. The cutting equipment cannot be allocated accordingly.

2) Air risk construction is relatively large, which may lead to safety problems.

3) The air is affected by wind and other factors, resulting in the construction quality can not be guaranteed, further affecting the management of construction progress. It can be seen that component inspection is the core step of the construction management route.

Therefore, the virtual pre-assembly must be carried out before the lifting of the ground lifting section. According to the results of virtual pre-assembly, the ground lifting section is cut in advance. The following is a workflow of the application routes of virtual pre-assembly technology in Raffles management,

which is a combination of the air corridor BIM and 3D laser scanning.

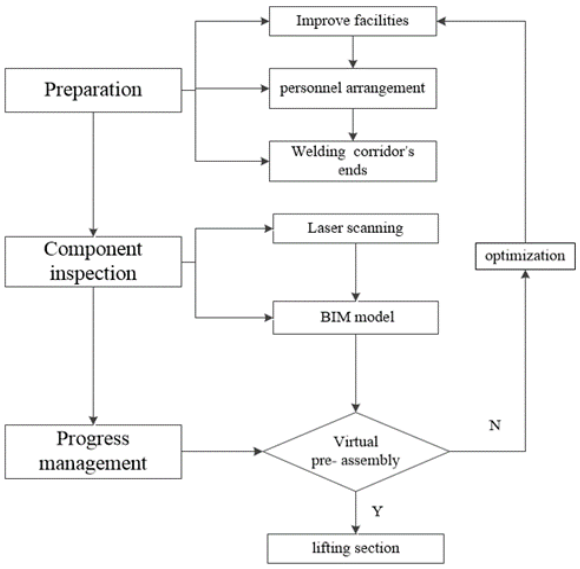


Figure 2. Construction management workflow of Chongqing Raffles

3.2 *Preparation stage*

Managers arrange relevant personnel to improve the equipment before construction, install the crane in place, and check whether the lifting device is in good condition. In addition, managers should focus on organizing personnel to weld the joints of the corridor.

3.3 *Component inspection*

3.3.1 *Data acquisition*

Because the ends of the corridor are located in different towers, they are far away. According to the actual situation, we decided to use Leica MS60 whole station scanner to collect the data at the ends of the corridor. The characteristics of this instrument are effective scanning distance and high precision. In addition, for the ground lifting section and its ends, we use the method such as X330 to complete the data acquisition. The instrument has the advantages of fast scanning speed and abundant laser point clouds, and it is suitable for close range scanning.

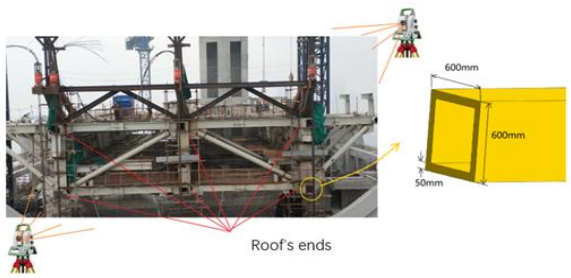


Figure 3. Scan the ends of the corridor

Figure 4. Scan the ground lifting section and its ends

3.3.2 *BIM model*

The collected point cloud completed the preprocessing work such as station collage and drying. The corrider and the ground lifting section's ends are key features, which directly determine the results of corridor assembly. In the point cloud processing software Geomagic Control, the corresponding algorithm is used to get the spatial parameters of all the end heads, which are saved in A and B matrices. The data of A and B will update the BIM model, so that the designed BIM model can be converted into the actual BIM model(Figure 5).

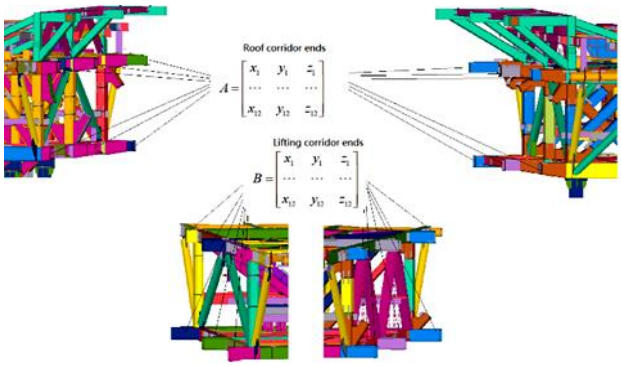


Figure 5. The BIM model of corrider's ends

3.4 *Progress management*

3.4.1 *Progress forecast*

The result of virtual pre-assembly is the key index of progress prediction. Only when the result of virtual pre-assembly meets the progress requirements can the construction be carried out(Figure 6). Virtual pre-assembly is a way to predict the progress ahead of time.

It is worth noting that the influence degree of the axial deviation (x direction), transverse deviation (Y direction) and vertical deviation (z direction) on the structure is different. According to the finite element analysis and simulation, the closure deviation in Z direction has the greatest influence on the structural stress, and the deviation cannot exceed 25 mm.

The results of virtual pre-assembly show that the construction requirements can be met only when the

4 end of the corridor is cut. The managers decided to cut the end 4 to avoid subsequent construction risks.

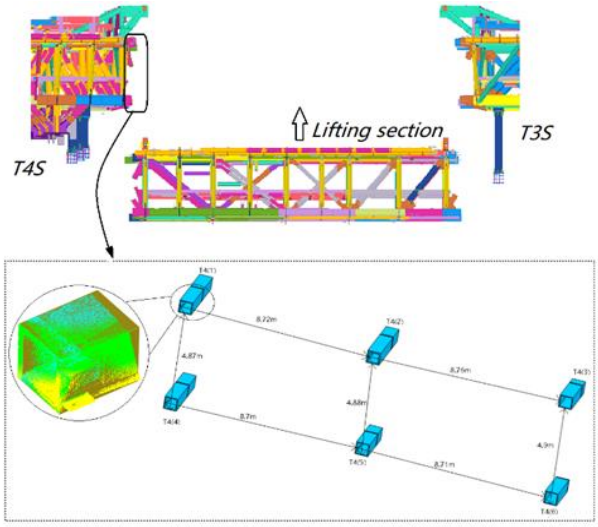


Figure 6. The BIM model of ground lifting section's ends

The following is the result of virtual pre-assembly in Z direction(Figure 7).

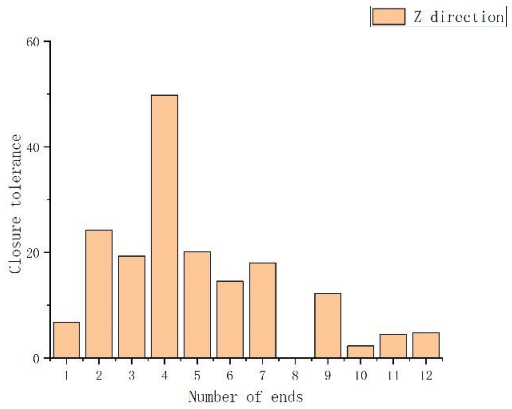


Figure 7. The result of virtual pre-assembly

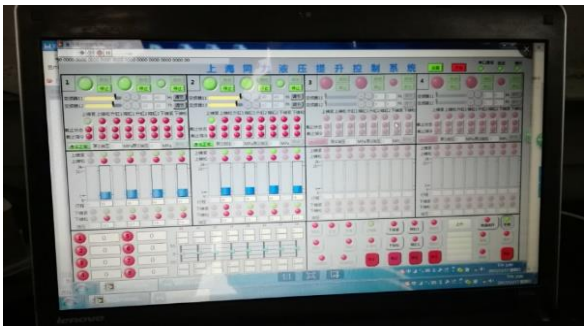
3.4.2 *Optimization preparation*

The managers shall organize relevant personnel to cut the unreasonable end 4, and the cutting requirements shall meet the deviation range. Compared with the previous arrangement of personnel and facilities when closing upstairs, the managers's strategy avoids the arrangement of this operation.

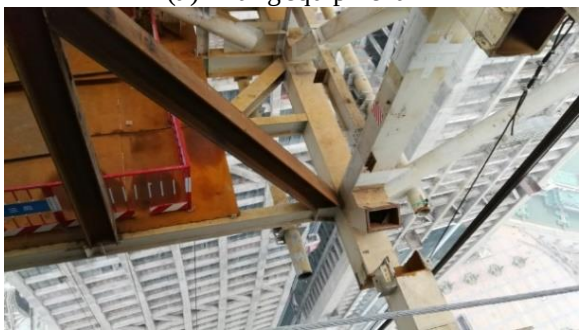
3.4.3 *Guarantee the construction progress*

As the corridor lifting is strictly controlled according to the pre-assembly results, the corridor construction process is smooth. It not only improves the efficiency of construction, but also ensures the quality of construction(Figure 8).

(a) Lifting equipment



(b) Controller



(c) Closure

(d) Closure completed

Figure 8. Corridor's construction

4 REPRESENTATION OF RESULTS

The three-dimensional laser scanner accurately scaned the end of the corridor and related components, and accurately obtained the key features needed for virtual pre assembly. Virtual pre-assembly predicted that No. 4 end was unqualified, and managers organized personnel to cut No. 4 end in advance. This measure effectively avoided the situation that the corridor installation was not smooth, and also avoided the risk of high altitude adjustment of the corridor. The manager effectively managed the whole process of corridor construction, improved the efficiency of site construction, and ensured the mechanical performance of corridor

5 CONCLUSION

BIM and virtual pre-assembly technology can accurately simulate the construction process of the structure, especially the prefabricated structure, and finally evaluate the simulation results from the mechanical point of view. The results show that the method can obtain reliable simulation results. In this way, the hidden danger of structure manufacturing can be found in advance. If managers can effectively combine the technology, they can achieve the following management functions:

1) Improve the efficiency of building construction. Before the construction of the building, the advanced simulation can be carried out, and the managers can find and solve the problems in advance. This avoids the more likely cost of solving the problem halfway.

2) Reasonable allocation of resources. The simulation results can make the managers optimize the construction preparation steps, arrange the constructors more reasonably, and improve the corresponding facilities.

3) Ensure the quality of construction. This involves the optimization problem, that is, we need the optimal construction scheme according to the actual situation. Managers can use virtual pre-assembly to achieve this goal.

4) Avoid construction risks. The high altitude work risk is very big, the managers through this technology can effectively avoid arranging the construction personnel to carry on the high altitude work, guarantees the construction to carry on smoothly. In addition, due to the high stress requirements of the structure, the structure beyond the acceptance range is unsafe.

BIM and virtual pre-assembly technology can play a great advantage in construction management. Further, how to quantify the contribution index of management in construction project is worth studying.

6 ACKNOWLEDGMENTS

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