Design and optimization of prefabricated component system based on BIM technology

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Abstract. Building industrialization is a new trend in the development of the construction industry, which is characterized by the implementation of standardized design, industrialized production, mechanized construction and information management in the process of building production. The combination of BIM technology and the design and construction of prefabricated structure can give play to the advantages of BIM information integration and realize the integration of design, production, construction and operation and maintenance. In this context, in order to maintain the good functional characteristics of the prefabricated component system and enhance its potential application value in practice, it is necessary to realize the design and optimization of the system under the support of BIM technology, so as to meet the requirements of the sustainable development of the prefabricated component system. This method with prefabricated library as a starting point, choose the component library of prefabricated assembly design, form a whole structure BIM model, along with analytical review, collision checking, etc., inspection, adjustment and optimization of BIM model, according to the proposed file encryption algorithm to encrypt files, and eventually form a reasonable design scheme of BIM model guide production, transportation and assembly of prefabricated construction.

1. Introduction
Focusing on the design and optimization analysis of the prefabricated component system based on BIM technology is conducive to enhancing the practical application effect of the prefabricated system, improving the service function and ensuring the good application condition[1-2]. Therefore, it is necessary to actively carry out the design of prefabricated component system through the scientific use of BIM technology in practice, and give necessary attention to the optimization process, so as to continuously improve the practical application level of the system[3-5]. At the same time, scientific evaluation should be conducted on the design effect and optimized application effect of the prefabricated component system supported by BIM technology, so that the system can play its due role in the application of the architectural field and meet the long-term development requirements of modern prefabricated buildings[6-7].

So-called BIM technology, it is short for building information model technology, is based on the three-dimensional digital technology, is on the engineering practice, using the data integration, and in the engineering data model and the matching between the parametric entity modeling technology, improve the building design, improve design efficiency and quality. BIM originated from the architectural computer simulation system proposed by the United States at the end of the 20th century[8-9]. BIM technology was introduced into the construction industry in 2002. After more than ten years of
development, BIM technology has become a revolutionary technology in the American construction industry. Based on the relevant information and data of each stage of the construction project, BIM establishes the building model. BIM technology is the embodiment of the construction industry in informatization. In each stage of a construction project, 3d information technology is used to integrate all the information and data of the project into an engineering model[10]. The use of this model can achieve the integration of the design and construction of the construction project and make all the majors work together. In the process of design and optimization of prefabricated component system, if attention is paid to the use of BIM technology, it will be beneficial to enrich the design content and design method of the system, and make the prefabricated system in a good state of development in the process of practice. The real BIM can comprehensively describe the information of the construction project, and the project participants can obtain and use the information according to their own needs at the same time, so as to achieve the consistency of planning, design, construction, operation and maintenance. A true BIM has the following characteristics:

(1) Visualization. For the traditional two-dimensional construction drawings, engineers can only rely on the brain to imagine the shape of the components. Engineering projects are increasingly complex and rely on imagination. BIM visualization enables building components to be visually displayed to engineers in a three-dimensional manner, and project communication, discussion and decision-making can be carried out in a visual state.

(2) Coordination. There are many majors involved in the design process of architecture, and if the communication and coordination between different majors cannot be achieved during the design process, the coordination of BIM can solve such problems by coordinating the design of different majors before construction to avoid collision problems and minimize conflicts among different majors.

(3) Simulation. BIM technology can provide sunshine, heat conduction, building energy saving and application to buildings before construction. It can also simulate the operation and maintenance phase of the fire escape and other emergency emergency treatment scheme.

(4) Optimization. The design, construction and operation and maintenance of the project is a process of continuous optimization. Engineering designers provide reliable and detailed information and data of geometry, physics, rules and other buildings for optimization design. When modern buildings reach a certain level of complexity, engineers must rely on BIM and supporting optimization tools for optimization.

(5) Graphicability. BIM can not only produce common construction drawings, but also coordinate and mold. Proposed and optimized comprehensive pipeline drawing, comprehensive structure reserved hole drawing, collision inspection and detection report and proposed improvement plan. The so-called prefabricated component system refers to the system closely related to the prefabricated components, which can provide guarantee for the efficient utilization of the prefabricated components, thus meeting the long-term development requirements of modern prefabricated buildings[11-12]. In practice, if the construction and use of prefabricated component system can be emphasized, the green construction requirements in the construction field can be met, and the resource allocation in the project construction can be optimized, so that the application range of prefabricated component can be continuously expanded, thus injecting vitality into the long-term development of prefabricated building. Therefore, more consideration should be given to the application of BIM technology in design and optimization based on the understanding of the functional characteristics of prefabricated buildings, so as to promote the application of prefabricated component system with reliable performance to a larger range[13-14].

2. Traditional prefabricated structural design method
During the construction of prefabricated buildings, the constructors, designers, producers and constructors need to cooperate closely and coordinate their work so as to ensure the smooth construction process[15]. Compared with the cast-in-place structure, the design of the assembly-type structure presents the characteristics of process refinement, design module, coordination integration and cost...
precision. The design stage is mainly divided into five stages: technical planning, scheme design, preliminary design, construction drawing design and component processing drawing design. After the completion of the design can be carried out component production, into the construction stage. In the technical planning stage, the design unit can fully understand the project construction scale, positioning, objectives, cost limits, etc., develop reasonable technical strategies, and jointly determine the corresponding technical scheme with the construction unit. In the scheme design stage, the horizontal elevation design is carried out according to the technical strategy, and the design standardization and "fewer regulations" are realized on the premise of satisfying the use functions.

The goal of "multi-grid and multi-combination", and give consideration to diversification and personalization. In the preliminary design stage, we carried out collaborative design with various majors, optimized the types of prefabricated components, fully considered the requirements of various majors, conducted cost impact factor analysis, and formulated economic and reasonable technical measures. In the construction drawing design stage, the design shall be carried out in accordance with the formulated technical measures, and the reserved and embedded requirements of each profession shall be fully considered in the construction drawing. In the stage of component processing drawing design, the component processing drawing is generally completed by the design unit and the component factory, and the architectural specialty provides prefabricated dimension control drawing as required.

3. Discussion on design and optimization of prefabricated component system based on BIM technology

Combined with the application advantages of BIM technology and the actual situation of prefabricated component system, in the process of the system design and optimization, if the scientific use of BIM technology can be realized, the ideal design scheme of prefabricated component system can be obtained to ensure good optimization treatment effect. When carrying out the research work on the design and optimization of prefabricated component system based on BIM technology in practice, the following aspects can be taken into consideration.

3.1. Visual design and unique groups

Since BIM technology has the advantages of visualization, it is necessary to realize the visualization design of prefabricated component system under the support of this technology in the process of design and optimization of prefabricated component system, and fully consider the special groups in the system optimization. It is embodied in the following aspects:

(1) Based on BIM technology of prefabricated component design visualization system, by considering the actual situation prefabricated frame structure, in three dimensional space structure situation of prefabricated components in the system components, node connection effect, such as dynamic simulation analysis, and in the way of visual design, the construction situation of prefabricated component structure, the use function of different component analysis. During this period, can use BIM model of prefabricated components in the system components of the node of regional connectivity for real-time analysis, satisfies the requirement of visualization in the design of the system, and with BIM technology support for this type of system involves the node connection method to conduct a comprehensive inspection, to ensure that the design effectiveness of prefabricated components and node connection is in good condition.

(2) With the support of BIM technology, when optimizing the prefabricated component system, it is necessary to give full consideration to the relevant specific groups. Specifically, through the rational use of BIM technology, the graphic element information in the building component system is collected, analyzed and utilized efficiently in the three-dimensional computer space. Under the action of the method of family definition, the graphic element information resources of prefabricated components are integrated to enrich and elaborate the related family library definition. The family creation process is performed in predefined templates, and various parameters such as distance, material, visibility, etc. can be added to the family according to the user's needs. At this point, the designer does not have to spend additional time to make the family file, and give parameters, but directly import the corresponding
family file, can be directly applied to the project; When the drawing of family files in the optimization process of prefabricated component system based on BIM technology is completed, the parameters related to components can be automatically adjusted, and the efficient use of building models containing detailed information of various specialties can be realized. Therefore, when optimizing and analyzing the prefabricated component system in the three-dimensional computer space under the influence of BIM technology, more consideration should be given to the specific groups concerned, that is, under the support of family files, the optimization of prefabricated component system should be realized to maintain the good operating conditions of this kind of component system.

3.2. Effective collision inspection of steel bar level of component connection

In the design and optimization of prefabricated component system based on BIM technology, it is necessary to consider the effective collision inspection of steel bars of component connection during the deepening design and optimization of the system through the scientific use of such technology, so as to avoid the potential safety risks for the operation of the prefabricated component system due to the design error collision. It is embodied in the following aspects:

(1) In the prefabricated component in the process of system design and optimization of reinforced level can be formed through BIM technology collision check, prefabricated in file processing, there is no internal steel collision problem, the key in the node connection area: due to the steel reinforcement, stirrups and board here will be intensive, probably collision problems. At this time, designers can use BIM technology to carry out the collision inspection of prefabricated components, and find out the possible design problems in time, including the name of the collision object, collision type, component type, etc., so as to avoid adversely affecting the application process of the prefabricated component system.

(2) The prefabricated components in the process of system optimization, to achieve this kind of component function optimization purposes, you need to relevant personnel in the design of support, the use of BIM technology in the three-dimensional space of prefabricated components connected reinforced level in the performance of the reliability for scientific evaluation, deal with the problems, and make the resulting prefabricated components can meet the actual requirements of building construction. On this basis, it can realize the efficient use of the assembled components, and make the related system optimization processing more targeted.

3.3. Quantity statistics in design

Through to the scientific use of BIM technology, in the process of system design and optimization of prefabricated components, through the reasonable choice of professional software, but will include engineering information database used in prefabricated component in the design of relevant quantities, prompted the final design scheme of prefabricated component system more perfect, satisfy the requirement of the optimization of processing work. It is embodied in the following aspects:

(1) In the prefabricated components in the system design, designers can with BIM technology support, in the computer 3 d space by using professional software, statistical analysis of relevant quantities of prefabricated components to reduce this kind of component quantity for errors in statistical probability, meet the requirement of prefabricated construction cost of the whole product process control, and prompted prefabricated component in the operation of the system have good cost efficiency. At the same time, based on BIM technology of prefabricated components related statistical analysis of quantities of work, need to relevant personnel can in practice to integrated use of the data information, and better control the component quantity statistical process, so as to bring the quick construction of prefabricated building, and keep the prefabricated component system working condition of good design.

(2) In the prefabricated component system based on BIM technology optimization analysis, through statistical analysis of relevant quantities of such component, based on the ideal statistical analysis results, also need to relevant personnel can achieve the efficient use of statistical analysis results of quantities, system optimization for prefabricated components processing work for reference, comprehensively promotes prefabricated components working level in the process of practice.
3.4. *Simulated construction in practice*

Based on the judgment and analysis of the situation change in practice, the design and optimization of the prefabricated component system based on BIM technology should also be taken into consideration for the simulated construction in practice. Embodied in: (1) through the rational use of BIM technology, from cost economy, project feasibility, etc., to ensure that the system under the action of prefabricated components of construction design, and then work for relevant construction design to provide scientific guidance, and computer three-dimensional dynamic simulation analysis was carried out on the prefabricated building construction process, make the required in the construction of this kind of building construction plan formulation and implementation of more rational; (2) with BIM technology support, through the simulation assembly construction condition of prefabricated components practice scientific analysis, to the corresponding construction scheme is reasonable in comprehensive consideration, prompting prefabricated construction work could be carried out effectively, and broaden the prefabricated components the working train of thought of system design and optimization. Therefore, construction enterprises and personnel should pay attention to the efficient utilization of BIM technology when conducting construction simulation analysis in the application of prefabricated components.

3.5. *Optimization of working mode*

BIM consultant's receiving the landlord will provide the construction drawings of the modeling, design problem feedback to the owner, the owner organization BIM technology coordination meeting invitation design with BIM model reflects on the BIM consulting party confirm, the design problem of BIM consulting sides according to the coordination meetings for integrated optimization of the BIM model, after the optimization plan is confirmed by the owner, design, construction CAD output results to issue a blueprint by the designer for the construction.

BIM optimization model of construction management, through the project management platform will BIM model associated with the field, to carry out the BIM model construction of mechanical and electronic solutions, and through the management platform of specific functional plate to the problem of site construction management (including supervision of open access to real-time feedback to the problems of site construction, the construction of the open access to timely response to the work plan, open access to the owners of site construction state real-time monitoring, etc.), the overall management of the whole project construction process, the detailed flow chart shown in figure 1.
FIG. 1. Flow chart of prefabricated component optimization system based on BIM technology

Construction technology disclosure: detailed disclosure of key and difficult parts in the construction process (including outdoor pipelines, pipe Wells, machine rooms, etc.) by combining the three-dimensional view with the plan. Carry out standardized simulation display of construction technology and engineering samples to ensure construction quality.

The depth level of the BIMT optimization model is divided into four levels, namely LOD100, LOD200, LOD300 and LOD400. The owner shall determine the level of the BIM model through consultation with the consultant according to the specific requirements. The specific depth requirements of the model are as follows:
### Table 1. BIMT optimization model depth

| Depth series | Describe |
|--------------|----------|
| LOD100       | Planning and design stage |
| LOD200       | Preliminary design stage |
| LOD300       | Construction drawing design stage |
| LOD400       | The construction phase |

#### 3.6. File encryption algorithm implementation

The implementation of the file encryption algorithm proposed in this paper includes the key extension process and the encryption process. Take the key length of 128 bits as an example, the encryption process includes an initial key addition as the initial round, followed by 9 rounds of transformation, and finally a round of transformation, as shown in figure 3:

![Figure 2. The entire encryption process (the key length is 128 bits)](image)

The input and output of the proposed file algorithm can be viewed as a one-dimensional array in bytes. For encryption, the input is a plaintext group and an initial key, and the output is a ciphertext group. For decryption, the input is a ciphertext group and an initial key, while the output is a plaintext group. The wheel transformation and each step of algorithm act on the intermediate result, which is called the state. A state is a byte array that can be visually represented as a matrix of four rows. The number of columns in the state matrix is Nb, which is equal to the number of bits in the data packet length divided by 32. Group the plaintext as:

\[ p_0 p_1 p_2 p_3 \ldots p_{4Nb-1} \]

Where \( p_0 \) represents the first byte of the plaintext group and \( p_{4Nb-1} \) represents the last byte of the plaintext group. Similarly, ciphertext grouping is denoted as:

\[ c_0 c_1 c_2 c_3 \ldots \ldots c_{4Nb-1} \]

Let's call the state: \( s_{i,j}, 0 \leq i < 4, 0 \leq j < Nb \)
Here, \( s_{i,j} \) represent the bytes in the \( i \)th row and \( j \)th column of the state matrix. Input byte in turn is mapped to a state \( s_{0,0}, s_{1,0}, s_{2,0}, s_{3,0}, s_{0,1}, s_{1,1}, s_{2,1}, s_{3,1}, \ldots \). When encrypting, the input is a clear text group and the mapping is
\[ s_{i,j} = p_i + 4j, 0 \leq i < 4, 0 \leq j < N_b \]
When \( N_b = 4 \), the plain-state matrix mapping is shown in table 1:

| P0 | P4 |
|----|----|
| P1 | P5 |
| P2 | P6 |
| P3 | P7 |

Similarly, when decrypted, the input is a ciphertext group and the mapping is
\[ s_{i,j} = c_i + 4j, 0 \leq i < 4, 0 \leq j < N_b \]
When the encryption ends, ciphertext packets are extracted from the state matrix in the same order.
\[ c_i = s_i \mod 4, i/4, 0 \leq i < 4N_b \]
When decryption is complete, the plaintext grouping is extracted from the state matrix in the same order,
\[ p_i = s_i \mod 4, i/4, 0 \leq i < 4N_b \]
Similarly, the initial key is mapped to a two-dimensional key matrix. The key matrix can be represented visually as a matrix similar to the state matrix, which also has four rows. The number of columns in the key matrix is \( N_k \), which is equal to the number of bits of the initial key length divided by 32.

When \( N_k = 6 \), the mapping of the initial key-key matrix is shown in table 2:

| K0 | K4 | K8 | K12 | K16 | K20 |
|----|----|----|-----|-----|-----|
| K1 | K5 | K9 | K13 | K17 | K21 |
| K2 | K6 | K10| K14 | K18 | K22 |
| K3 | K7 | K11| K15 | K19 | K23 |

Process of data block operation during encryption and decryption: now \( a_0, a_1, a_2, a_3, a_4, \ldots, a_{15} \) is copied to the state array; Encryption and decryption process of the state of the technical processing; At the end of the encryption and decryption process, the state group will be copied to \( b_0, b_1, b_2, b_3, b_4, \ldots, B_{15} \). Finally get the output result of encryption and decryption. The operation mapping process is shown in figure 3:

\[
\begin{pmatrix}
  a_0 & a_4 & a_8 & a_{12} \\
  a_1 & a_5 & a_9 & a_{13} \\
  a_2 & a_6 & a_{10} & a_{14} \\
  a_3 & a_7 & a_{11} & a_{15}
\end{pmatrix} \Rightarrow \begin{pmatrix}
  S_{00} & S_{01} & S_{02} & S_{03} \\
  S_{10} & S_{11} & S_{12} & S_{13} \\
  S_{20} & S_{21} & S_{22} & S_{23} \\
  S_{30} & S_{31} & S_{32} & S_{33}
\end{pmatrix} \Rightarrow \begin{pmatrix}
  b_0 & b_4 & b_8 & b_{12} \\
  b_1 & b_5 & b_9 & b_{13} \\
  b_2 & b_6 & b_{10} & b_{14} \\
  b_3 & b_7 & b_{11} & b_{15}
\end{pmatrix}
\]

Input data \hspace{1cm} Intermediate result (state) \hspace{1cm} Input data

Figure 3. Operation mapping process

4. Conclusion
The scientific use of BIM technology can provide the necessary technical support for the design and optimization of the assembled component system, further encrypt the files, improve the system security, realize the efficient use of the system, and maintain the good development of the construction field. Therefore, in the future, when designing and optimizing the prefabricated component system, relevant personnel should pay attention to the efficient utilization of BIM technology and put in place the research on the design and optimization of the prefabricated component system under the influence of this technology, so as to comprehensively improve the application level in the field of architecture. On this
basis, it can enrich the practical experience in the design of assembly-type component system, and ensure the effectiveness of technology application in the design and optimization process.

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