Parametric Design and Application of Assembled Steel Plate Composite Beam Bridge Based on BIM Technology

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Abstract. This paper combines Building information model (BIM) technology with assembled steel composite beams, carries out parametric design and Deepening Application in Revit software, optimizes BIM technology with other software, proposes parametric design process based on Revit as three-dimensional core modeling software, and carries out virtual analysis of bridge real environment. The BIM information classification and coding of the components of the assembled composite girder bridge lay the foundation for the establishment of BIM information model. Based on Dynamo visual programming, the input efficiency of information integration is improved by batch input of parameter information values. Based on the BIM model and Abaqus finite element software, the stability of the 2×5 m prefabricated pier is verified and analyzed.

1. Research background and significance

1.1. Research Background
Steel plate composite girder bridge, which originated in Europe in the 20th century, is a structure with reasonable structure, outstanding economy and easy construction, and has good comprehensive technical and economic benefits. With the deepening of theoretical research and the popularization of technical application, the structural form of steel plate composite beams has been greatly optimized, and the durability and economy of the structure have been significantly improved. Referring to the mature technology of steel plate composite bridge abroad, China has made considerable development and more and more extensive application [1]. Compared with concrete beam bridge, steel plate composite beam has smaller height, lighter self-weight, higher ductility, lower cost of foundation and shorter construction period. Compared with pure steel bridges, small and medium span steel plate composite beams have more advantages in bearing capacity, stiffness and overall cost.

BIM technology has both innovative production tools and new production methods, bringing great innovation to the construction industry in developed countries in Europe and America. A large number of successful application cases have proved its great value advantages. The popularization and application of BIM make the traditional bridge industry find a breakthrough in improving efficiency, promoting industrialization and realizing information management [2].

BIM technology and assembled composite girder bridge system have consistency and complementarity in many aspects:

1) In order to realize the process from design to construction of assembled composite girder bridge, coordinated cooperation of all participants is needed. BIM technology is highly cooperative, which
can meet the integration and sharing of bridge information data by all parties in the project.

2) When using standardized and modular methods to design assembled bridges, there will be many duplicate data and work. The parameter driving based on BIM technology can effectively avoid the problems of "mistakes, leaks, collisions and deficiencies" [4] and improve work efficiency.

3) Based on BIM technology, it can be applied to the whole life cycle of bridges, which is consistent with the management objectives of assembly bridges to achieve the whole life cycle of bridges.

1.2. Research Significance
As new information technology, BIM has the advantages of high efficiency, good economic performance, information management, energy-saving and environmental protection when applied to bridge construction. It can not only realize the transmission and sharing of BIM information model in the whole life of the project, but also can interact with the model, three-dimensional visualization, collision detection and construction model. The core of assembly system lies in integration, and the core of BIM lies in highlighting information integration. The combination of the two effectively promotes the development of assembly system. Therefore, the research of assembly steel plate composite bridge system based on BIM technology meets the needs of upgrading the bridge industry and is conducive to promoting industrialization and information of small and medium span bridges.

2. Parametric Model Design Method and Information Classification Based on BIM

2.1. Virtual Environment of Bridge Based on BIM Technology
Civil 3D and InfraWorks360 are simulation visualization software oriented to infrastructure field for Revit. In building design model and Bridge geographic information, these software can be used for rapid modeling. The specific idea is to integrate bridge design data and determine the geographic location of the bridge project through the function of Infraworks360 satellite image, and quickly establish the terrain model, and import file into Civil3D for elevation of the geographic environment composed of the surrounding elements. The data and bridge pile number are processed, and the specific coordinates of the project are determined by using the existing DWG topographic data. Then the processed topographic map is imported into Revit for data interaction, and the three-dimensional geological reconstruction is realized by creating topography. The basic axle network and engineering base point are set to determine the bridge position.

2.2. Design Ideas
Bridge design process generally includes conceptual design, scheme design, preliminary design, construction drawing design and so on. In this regard, based on BIM technology, the corresponding BIM software can be used in different design stages to meet the needs of the design results in this stage. This paper takes Revit as the three-dimensional core modeling software, takes the assembled steel plate composite beam with 4×20m span as an example, combines Navisworks, Lumion and Abaqus of Autodesk platform, and proposes a parametric design method based on BIM technology to meet the requirements of standardized design and industrial production of steel plate composite beam bridge. In order to improve the efficiency of BIM modeling and maximize the advantages of "family" unit modeling with parameters provided by Revit software.

The specific process steps are described as follows. The first step is to simulate the bridge environment. The second step is to split and parameterize the components and input the BIM code. The third step is to establish the standard component family. The fourth step is to adjust the shared parameters. The fifth step is to assemble the bridge and arrange the steel bundles, output drawings and detailed lists. The sixth step is to detect the collision. The seventh step is to check whether the collision detection is qualified, if it is unqualified return to the fourth step, if qualified for the next step. The eighth step model stress calculation. The ninth step is optimization design and completion of the creation.
2.3. Modeling Criteria

At present, BIM is still in the initial application stage in bridge. There are no specific regulations and standards for modeling standards. Therefore, referring to the unified standard of building information model and the practical application of engineering, this paper tries to put forward the modeling criterion suitable for assembled steel plate composite girder bridge.

1) Coordinate system: The basic coordinate system is the right-handed Cartesian coordinate system. The X-axis is transverse, the Y-axis is longitudinal, and the Z-axis is vertical.

2) Model unit: the length unit of whole bridge is unified into cm, the accuracy is controlled within decimal places, and the size is reduced in an appropriate proportion to build whole bridge model.

3) In design stage, the model accuracy is LOD300, and in construction stage, the model accuracy is LOD400.

4) Establish the component family library of steel plate Girder Bridge. The geometric and non-geometric information of each component family are correlated by shared parameters.

2.4. Information Classification

Under the concept of bridge life cycle design, in order to realize BIM information collection and promote information management of steel plate composite girder bridges, it is necessary to classify and code the relevant information of structural components, participants and stages in accordance with certain rules, and to store, consult and modify the code by endowing the information of various elements. It can be used to distinguish the prefabricated members and to design the assembled steel plate composite beam bridge rapidly. At present, under the Chinese Building Information Model Standard (CBIMS)[4], the information classification system mainly adopts hierarchical codes, including table coding, large class code, middle class code, small class code and fine class code. Table coding and classification code are connected by “-”, other class codes are separated by English “.”, and all levels of code are separated by two Arabic numerals.

3. Establishment of Design Model of Steel Plate Composite Beam Bridge Based on Revit Platform

3.1. Selection of Design Parameters

The parameters in Revit software can be divided into family parameters, shared parameters, project parameters and global parameters. Since the shared parameters are not directly defined in a single family or project, but independently defined in advance for storage in multiple families or projects, after adding shared parameters to the model, the parameters can also be converted into family parameters or project parameters for use. Therefore, in order to adjust and modify the BIM model rapidly in the design stage, before creating the model of steel plate composite girder bridge, it is necessary to split the components reasonably and select appropriate control parameters. Based on the above principles, the main control parameters of BIM model of assembled steel plate composite bridge are proposed. The construction method is factory prefabrication and field hoisting and splicing. The main girder bolt connection and web welding are adopted in connection form. The number of shear nails is one hundred and eleven. The construction method of prefabricated pier is transportation hoisting. The connection between piers and columns is grouting sleeve. The connection mode between pier and cap is socket type. Some other basic data are shown in Table 1.

| Material type       | Q345qD |
|---------------------|--------|
| Upper flange thickness | 2.2   |
| Lower flange thickness | 3.2    |

Steel girder

| Shear nail spacing(portrait) | 20 |
| Shear nail spacing(transverse) | 12 |
| Bottom width | 70 |
| Vertical rib spacing | 100 |
|                         |                        |
|-------------------------|------------------------|
| Web thickness           | 2.2                    |
| Length of steel girder  | 800                    |
| Height of steel girder  | 120                    |
| Roof width              | 60                     |
| Reserved void diameter  | 1.5                    |

**Reinforcement**
- HRB400, longitudinal steel
  - φ18, hooping φ10

**Grouting material**
- C80 High strength cement

**Sleeve type**
- 45#

**Concrete grade**
- C50

**Pillar height**
- 50.00

**External diameter of pier**
- 150.00

**Inner diameter of pier**
- 120.00

3.2. *Establishment of Standard Component Family*

Based on the Revit 2017 software platform, the standard component families are established step by step according to the mode of component splitting and coding information. By defining the basic type of shared parameter-driven model, the component dimensions are updated automatically after adjusting the family parameters, and then the component families are joined into the full-bridge BIM model in turn after adding non-geometric information. In this paper, when creating the upper and lower structures, the basic data are input into Revit 2017 software platform to achieve rapid creation.

The BIM model of the bridge design level is created according to the logic from bottom to top, and the standard family members are placed and spliced into the structural framework model according to the category in turn. The splicing process is as follows:
The parameterized standard component family established according to component classification and information coding is stored in the family library. For other components with the same standard or similar components, it can be directly transferred from the family library. After adjusting the parameter information, it can be spliced into a design model, which can be directly used to guide prefabrication production and construction. This parametric method can reduce the repetitive modeling work, improve the efficiency of modeling, and meet the requirements of standardized design and industrial production. In addition, the BIM model of steel plate composite girder bridge established by Revit has interrelated internal parameters. When an object in the model changes, all the corresponding parameters will be automatically updated to achieve "one change and overall change".

4. Fast integration based on Dynamo parameter information
This paper adopts the visual programming of Dynamo secondary plug-in based on Revit, which can input data from Excel tables into the model quickly and flexibly through the way of program flow. The concrete method is to divide the information in bridge model components into basic types, such as component construction information, mechanics information, text information, identification data and phased information. The family type attribute bar of the component in the project is taken as the basic framework of information integration, and then phase is added in the Revit management module according to the requirement. The corresponding family type project parameters, and in Excel table to establish data consistent with the project parameters, and finally through the establishment of Dynamo program flow to achieve the automatic input of project parameters.

5. Finite element analysis based on BIM model
At present, the experimental study of assembled piers seldom involves the mechanical properties between assembled double-column hollow piers. In order to verify the energy of the connection between prefabricated hollow piers under external force, the mechanism of forming plastic hinge along and across the bridge is different. Based on Revit model, the buckling stability of the 2×5m assembled pier height is analyzed.

The substructure of the Revit model is imported into Abaqus to complete the model interaction. The cast-in-situ caps, prefabricated piers, prefabricated cap beams and grouting sleeves are simulated by solid elements, and the reinforced materials are simulated by beam elements. The steel sleeve and the upper and lower reinforcing bars are connected in a coupling way, the reinforcing bars and piers are connected in a built-in way, and the rest are connected in a common joint way. The load locates on the upper part of the bearing, which is vertical load and horizontal load along the bridge respectively. According to the most unfavorable load combination, the buckling analysis of the assembled pier is carried out. After the static calculation is simulated by Abaqus software, the first-order eigenvalue is 74.3 and the second-class stability coefficient is 15.4, which meets the stability design requirements.
6. Conclusion

In this paper, Revit is used as the three-dimensional core modeling software to parametric design and visualization application of 4×20 m assembled steel plate composite girder bridge. The main research results are as follows:

1) Explore the BIM technology design method and modeling criteria for assembled steel plate composite bridge. Based on CBIMS standard, the classification and coding of BIM information components of steel plate composite bridge are established.

2) According to design ideas and modeling criteria, the standardization of component family design can be promoted by creating parametric standard component family in Revit and driving the integration of BIM model of full bridge. By using the secondary plug-in Dynamo for visual programming, the parameter information of the component family in the project is batched into Revit, which improves the speed of model information integration, and the design process meets the requirements of standardized design and industrialization.

3) The BIM model of the prefabricated structure of the lower part of the bridge is extracted and imported into the finite element software Abaqus to interact with the model. The stability of the prefabricated pier with the 2×5 m pier height is checked, and the calculation results meet the design requirements.

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