Endowing BIM Model with Mechanical Properties -- Finite Element Simulation Analysis of Long-Span Corrugated Steel Web Continuous Beam Bridge

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Abstract: Taking the main bridge of Zhaojun Yellow River Super Large Bridge as the engineering background, this paper explores the application of BIM technology in the finite element simulation analysis of long-span corrugated steel web continuous beam bridge, and proposes to establish the model of corrugated steel web continuous beam bridge by using the parametric modeling method of Revit software, Dynamo visual programming software is used to extract the geometric parameter information of BIM model, and the method of data conversion between BIM model and finite element model is realized through Python language programming, so as to endow BIM model with mechanical properties, avoid repeated modeling, and improve modeling efficiency and accuracy. The finite element simulation of the converted model in Midas/Civil provides and support for bridge construction monitoring, and provides new ideas for the application of BIM technology and structural calculation in similar projects.

1. Introduction

BIM is the information technology revolution for the next time led by the engineering construction industry after CAD. It has the characteristics of visualization of operation, completeness of information, scalability, collaboration, simulation and drawing of information. Its application scope and depth in the entire life cycle of building structures have been deepened.

Structural finite element simulation is one of the key works of engineering design and construction monitoring. How to combine with structural finite element simulation is one of the key research directions of the in-depth application of BIM technology. Since the introduction of BIM technology into China, with the wide application of BIM technology, designers have more and more strong demand for data conversion between BIM model and finite element model. Many scholars have studied BIM Technology in structural finite element simulation [1][2][3][4]. Such as He Xiangping, Wang Hao and others [5] proposed a fast conversion method from BIM model to structural finite element model by using Revit API and C# language under the development environment of Visual Studio, and designed a model conversion program from Revit to MIDAS / Civil; taking ANSYS and ABAQUS software as the finite element analysis platform, Zhang Zheyuan [6] studied the transformation and analysis framework between BIM model and finite element model; Wang Xiongjue [7] tried to convert the BIM model established in rhino software into MCT command flow through programming, so as to realize the
conversion between BIM model and Midas/Civil finite element model; Chen Zhiwei, Wu Kun and others\cite{8} realized the conversion between Revit model and ANSYS finite element model in the form of APDL command flow; Chen Hao\cite{9} studied the application of BIM in the finite element simulation calculation of Chaobaihe bridge. With the deepening of research and application, the difference of data format is still the biggest obstacle to the transformation between BIM model and finite element calculation model. How to transfer the three-dimensional model to finite element calculation software completely and efficiently through BIM modeling software, so as to realize the integration of design and calculation, is still the most concerned problem of designers.

2. Difficulties in construction monitoring

Corrugated steel web slab bridge arose in the 1980s. Since then, scholars at home and abroad have carried out a lot of research and practice on this new bridge form. In 2005, China independently built the first corrugated steel web plate bridge Liangguangshanpo River Highway Bridge. Since then, Inner Mongolia Changchonggou Bridge, Juancheng Yellow River Bridge, Xingtai main canal bridge of South-to-North Water Transfer and other bridges have been built, and the bridge span is also increasing. The practice shows that the corrugated steel web slab bridge has the advantages of good economic benefit, good durability, more reasonable structural stress, simple construction and short construction period.

Zhaojun Yellow River Super Large Bridge is a control project under construction for Baotou West connecting line of Baotou Dongsheng section reconstruction and expansion project of Baotou Maoming expressway. It is located at the junction of Baotou City and Ordos. The whole bridge has a total length of 4.3km and 20 connections in total. It is divided into main bridge, North Cross embankment bridge and South Cross embankment bridge, and beach approach bridge on the north and south banks. The length of the first connection of the main bridge is 1520m, and 85m + 9 × 150m + 85m corrugated steel web continuous beam, and the superstructure is an 11 span corrugated steel web prestressed concrete continuous beam bridge with a main span of 150m. The single girder adopts the form of single box and single chamber straight web, and the left and right box girders are symmetrical about the bridge centerline. The top plate width of single width box girder is 12.75m and the bottom plate width is 6.75m. After completion, it will become the longest beam bridge in China.

The PC composite box girder with corrugated steel web of the superstructure of the main bridge of Zhaojun Yellow River Super Large Bridge adopts the top and bottom plate dislocation construction method as shown in figure 1. During the construction process, the concrete top plate pouring of section n-1, the concrete bottom plate pouring of section n and the installation of corrugated steel web of section n + 1 are carried out. The difficulty of construction monitoring of Zhaojun Yellow River Super Large Bridge is the monitoring of internal force and geometric shape during the cantilever pouring of the main beam.

![Figure 1. Schematic diagram of the synchronous ectopic construction method.](image-url)
3. **Bridge finite element simulation based on BIM**

With the help of Revit and its plug-in Dynamo, the data conversion between BIM model and Midas/Civil finite element model is realized by using MCT command flow as the intermediate medium.

3.1. **BIM modeling software selection**

The choice of BIM core modeling software is the first problem to realize the application of BIM technology. There are many kinds of BIM application software on the market, such as Revit software of Autodesk company, CATIA software of Dassault company, Bentley series software, etc. Revit software was first applied in the construction engineering industry. It is a modeling software widely used in the engineering construction industry. It has powerful functions of three-dimensional parametric modeling, data management and sharing. In recent years, its application in the bridge construction industry is also increasing. Dynamo, a powerful visual programming plug-in, can carry out special-shaped structure modeling through visual programming combined with Python language, and assist Revit management model engineering data management, making Revit more flexible in use, so as to meet the needs of practical engineering applications.

For the continuous beam bridge with corrugated steel webs of Zhaojun Yellow River Super Large Bridge, it is necessary to establish BIM models of concrete structure of roof and bottom plate and corrugated steel webs. In order to facilitate subsequent application, this paper establishes a parameterized BIM model of the main bridge of Zhaojun Yellow River Super Large Bridge by using the BIM modeling software Revit of Autodesk company as shown in figure 2, figure 3, figure 4, and gives relevant parameters to the model.

![Figure 2. Whole BIM model of the main bridge of Zhaojun Yellow River Super Large Bridge.](image)

![Figure 3. Main beam structure of main bridge.](image)

![Figure 4. Corrugated steel web connection structure.](image)
3.2. Data conversion between BIM model and finite element model

The traditional finite element simulation modeling is directly carried out in the finite element simulation analysis software (such as Midas/Civil). The modeling process needs more time and energy, and it is not easy to modify, resulting in problems such as heavy workload and poor accuracy of finite element analysis. This paper explores the conversion of BIM model data into MCT command flow that Midas/Civil can recognize, so as to realize the data conversion between BIM model and Midas/Civil model, reduce the workload of finite element modeling and analysis, and improve the accuracy. The parametric BIM model is established by Revit, and the parametric driving of BIM model is realized. Each beam section of the main beam has the geometric parameter information of the box girder section. In addition, each beam section adds the component code parameter information as the unique identification. The idea of data conversion between BIM model and finite element model is shown in figure 5.

Taking Zhaojun Yellow River Super Large Bridge as an example, the specific process of finite element simulation calculation based on BIM is as follows: firstly, through Dynamo visual programming, the component code is used as the identification code to extract the component geometric parameter attribute information in Revit model as shown in figure 6; secondly, the python program is written through the python script node in Dynamo and converted to the MCT command stream recognized by Midas/Civil as shown in figure 7; finally, open the generated MCT command stream with Midas/Civil and correct it to complete the data conversion from BIM model to finite element model.
3.3. Finite element simulation results based on BIM

In terms of model calculation parameter selection, relevant calculation and design parameter information in BIM model can be extracted. C55 concrete is adopted for the project, with elastic modulus of 3.45E4Mpa and linear expansion coefficient of concrete of 1.0E-5. Q345D steel is used for corrugated steel web and its connecting steel plate with box girder concrete top plate, diaphragm and steering block, with elastic modulus of 2.06E5mpa, thermal expansion coefficient of 1.2E-5 and calculated unit weight of 78.5kN/m3. The allowable axial stress is 200MPa and the allowable shear stress is 120MPa. The prestressed reinforcement adopts low relaxation 1860 steel strand. The diameter of a single steel strand is 15.2mm, the area is 139mm², the elastic modulus is 1.95E5Mpa, the standard strength is 1860MPa, and the coefficient of thermal expansion is 1.2E-5.

Combined with the division of construction stages, the axial force, bending moment, stress, dead load displacement, shrinkage and creep displacement and live load displacement of the main beam, as well as the cumulative deformation of the main beam in the construction stage and the manufacturing alignment of corrugated steel web can be simulated to provide technical parameters for construction monitoring.

4. Conclusion and Prospect

In this project, the main bridge model of Zhaojun Yellow River Super Large Bridge is established with the help of the powerful parametric modeling and data management ability of BIM core modeling software Revit. On this basis, the data extraction of BIM model and data conversion with Midas/Civil finite element model are realized with the help of visual programming software Dynamo, and the finite element structure simulation is carried out, which improves the efficiency and accuracy of modeling.

The integration of BIM and finite element analysis is a difficulty in the application of BIM technology. The in-depth application of BIM technology is inseparable from the integration with traditional structural analysis. Promoting the combination of BIM modeling and finite element analysis and endowing BIM model with the highest mechanical properties is not only an innovative breakthrough in BIM application, but also a key breakthrough in BIM forward design and BIM + monitoring.

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