Stability Analysis of High-Rise Steel Structure Joints Based on BIM Technology

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Abstract. Because of its light weight, good orientation, strong seismic performance, high degree of industrialization, and short construction period, steel structure has relatively high investment efficiency and is widely used at home and abroad. At present, steel structures have been widely used in various complex high-rise buildings. Many high-floor buildings have many changes in building shapes and large spans, and their analysis difficulty and accuracy requirements are very high. Therefore, the stability analysis of steel structures is particularly important. Under the action of strong earthquakes, the welded parts at the nodes of the assembled high-rise steel structure are prone to rigid fractures, which are the weakest parts in the entire steel structure frame, causing damage to the steel structure nodes, and severe damage can lead to the collapse of the entire frame. In view of this defect, it is necessary to pay attention to the research on the stability of the prefabricated high-rise steel structure nodes. In this paper, combined with BIM technology, taking high-rise buildings as the research object, the linear buckling analysis of the structure is carried out, and the buckling mode, buckling weak parts and buckling load of the structure are obtained. Through the analysis of these data, this article evaluated the influence of the giant beam of this structure on the structural performance.

1. Introduction
The fabricated high-rise steel structure is mainly connected by welding or bolts, which has the advantages of large use area, short production cycle and high comfort. Under the action of strong earthquakes, the welded parts at the nodes of the assembled high-rise steel structure are prone to rigid fractures, which are the weakest parts in the entire steel structure frame, causing damage to the steel structure nodes, and severe damage can lead to the collapse of the entire frame. In view of this defect, it is necessary to pay attention to the research on the stability of the prefabricated high-rise steel structure nodes. The overall stability and local stability of the structure are mutually permeable. There are local stability problems in the overall stability, and the local stability will have a huge effect on the overall stability. For many large-span and large-space steel structures, because they have to consider both the stability and the dynamics of vibration, the two theories are referred to at the same time, so the analysis is more difficult. At present, the research results are still very limited, so the steel structure. The problem of dynamic stability needs to be solved urgently. Judging from the field of structural analysis at this stage, the research on the stability of steel structures has developed from static analysis to dynamic analysis; from elastic analysis to elastoplastic analysis. The analysis of nonlinear static stability and nonlinear dynamic stability of large space steel structures has become a hot topic for scholars at home and abroad.
2. BIM technology and stability analysis

The full English name of BIM is Building Information Modeling, and the more consistent translation in China is Building Information Modeling. BIM is an engineering data model based on three-dimensional digital technology that integrates various relevant information of construction projects. It is a digital expression of the physical and functional characteristics of engineering projects. Compared with the traditional construction method of relatively independent majors, complicated communication with each other, and uncontrollable man-made errors, the BIM model is based on computer data analysis and management. Different majors can update the model data at any time according to the needs of project construction. Collision problems can be found in time to improve work efficiency. At the same time, BIM technology builds a platform for information sharing and transmission based on data models. Different participants in the project can control the construction situation and effectively control the quality, cost and schedule of the project.

BIM technology completes the integration of the full information model, and integrates the classification work of each stage of the construction project. The information of different participants at different stages is completely preserved and interrelated. Through the guidance of BIM software, the construction project can progress smoothly in each phase (design phase, construction phase, operation and maintenance phase), eliminating the problem of cross-line and cross-phase information loss and error transmission in traditional design, and reducing different industries. The waste of resources and the delay of construction period are caused by the fragmentation. Based on the professional knowledge of architecture, this paper mainly studies the application of BIM technology in the design phase of steel structure housing and the component production and construction phases closely linked to the design phase.

The BIM software used in the steel structure deepening audit of this project mainly includes Tekla Structures (referred to as Xsteel), Midas Gen, Solid Works, ANSYS Work Bench, etc. ANSYS has a rich element library and powerful solver, and its structural analysis software package can better solve the static, dynamic, vibration and nonlinear problems of various structures. In this paper, ANSYS is selected to perform finite element analysis on the overall stability of steel frame beams. The use process of BIM technology is shown in Figure 1.
3. Finite element analysis of the stability of steel structure joints
Before conducting experimental research on the overall stability of steel structure joints, it is necessary to conduct finite element research. There are two main reasons for this: On the one hand, the finite element analysis method is the basic method for studying structural stability in modern times. The finite element analysis of the overall stability of the steel structure joints can provide reference for subsequent experimental research; on the other hand, there is a lack of research data for steel structure joints that can be used as a reference for overall stability test, and the requirements for test costs and test conditions are relatively high.

The analysis type corresponding to structural elastic stability analysis in ANSYS software is eigenvalue buckling analysis. The eigenvalue buckling analysis needs to turn on the prestress effect before the buckling analysis, and perform a static analysis of the structure under the reference load to obtain and save the geometric stiffness matrix of the structure. If the applied reference load is a unit load, the buckling load factor obtained is the corresponding buckling load. After defining the elastic modulus and geometric parameters of the material, the stiffness of the structure can be determined. After the geometric stiffness matrix is calculated and saved, the essence of the elastic buckling problem is to solve the problem of the eigenvalues of the large sparse matrix by iterative method. The stability of steel structure nodes will be analyzed in detail below.

3.1. Node model of assembled high-rise steel structure
Importing the fabricated steel structure node model constructed by Tekla structures into the design software can clearly show the relationship between the high-rise steel structure support column components and the basic steel components.
Use Revit to build the model of fabricated steel structure node, and build the steel structure node family with the idea of parameterization. Parameterization mainly describes the creation of a steel structure node family, and at the same time, according to the reference plane and the reference line, the high-rise steel structure components are coordinated according to the structural requirements. Fabricated high-rise steel structural components mainly include H-shaped steel columns, square steel pipe columns, column base plates, anchor bolts, etc. The support column of the high-rise steel structure is connected with the foundation member, and the position of the support column is adjusted according to the size requirements. After the construction of the high-rise steel structure node model is completed, the reinforcement is inserted. The node parameters are associated with the basic members during the entire node model construction process, and the structure center parameters are selected to control other parameters.

The transfer matrix of each element of the node model is successively multiplied to construct the transfer matrix of the node element, combined with the boundary conditions at both ends of the entire node model, the internal force or the stable bearing capacity of one of the end faces can be calculated.

3.2. Basic principles of eigenvalue buckling analysis

Structural elastic stability analysis solves a problem of solving eigenvalues in mathematical derivation, so it is called eigenvalue buckling analysis.

When the structural system is in a stable equilibrium state, the equilibrium equation obtained by the principle of potential energy standing value is shown below.

\[
([K_E] + [K_G])\{U\} = \{P\}
\]  

(1)

In formula (1), \([K_E]\) is the elastic stiffness matrix; \([K_G]\) is the geometric stiffness matrix; \([U]\) is the nodal displacement vector; \([P]\) is the nodal load vector.

According to the principle of minimum potential energy, when the equilibrium state of the structural system is the critical equilibrium state, the second-order variation of the potential energy of the system is zero, as shown in the following formula 2.

\[
([K_E] + [K_G])\{\delta U\} = 0
\]  

(2)

From formula 2, there is a non-zero solution:

\[
||[K_E] + [K_G]|| = 0
\]  

(3)

The elastic stiffness matrix in equation (3) is known, and the geometric stiffness matrix corresponding to the buckling load needs to be solved. After arbitrarily selecting a group of external loads with the same type and action form as the buckling load \([P^0]\) as the reference load, \([K_G^0]\) is known. If \(\rho[P^0]\) is used to represent the buckling load, then \([K_E] = \lambda[K_G^0]\), formula (3) can be transformed into the following formula.

\[
([K_E] + \lambda[K_G^0]) = 0
\]  

(4)

Write formula (4) in the form of eigenvalue equation.

\[
([K_E] + \lambda_i[K_G^0])\{\phi_i\} = 0
\]  

(5)

In formula (5), \(\lambda_i\) is the i-th eigenvalue; \(\phi_i\) is the eigenvector corresponding to \(\lambda_i\), and its physical meaning is the i-th buckling mode. In the eigenvalue buckling analysis of ANSYS, the output results are \(\lambda_i\) and \(\phi_i\); \(\lambda_i(P^0)\) is the buckling load of the structural system.

3.3. Stability analysis

The steps of using ANSYS to analyze the buckling of the structure are pre-processing, obtaining the static solution, obtaining the eigenvalue buckling solution, expanding the solution, and post-processing.

When the buckling analysis of the structure is carried out in this paper, the combination of dead seismic load is used to investigate the buckling behavior of the structure under the action of seismic load.
Because the buckling analysis is the same in all directions, this article only takes the direction for analysis. Here we take the seismic load from the response spectrum analysis load. The total bottom shear force of the structure is that the shear force is applied to the structure in an inverted triangle form, and the load results are shown below.

The buckling coefficients obtained from the analysis results are shown in Table 1 below.

| Buckling mode | 1   | 2   | 3   | 4   | 5   | 6   | 7   | 8   | 9   | 10  |
|---------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Buckling coefficient | 2.800 | 2.803 | 2.807 | 2.808 | 3.934 | 3.940 | 3.9 | 3.948 | 4.268 | 4.276 |

From the analysis results, the first-order buckling mode buckling of the structure occurs on the giant beams in the middle layer, and from the first step on the giant beams on the top layer, so the buckling path of this structure appears on the giant beams. The beam is the weak link. Secondly, the values obtained from the buckling coefficient table are all greater, that is to say, the buckling load of the structure is equal to these values multiplied by the seismic load we applied above, so we can judge that the structure has not buckled under the action of the earthquake. Because we only consider the seismic force in the direction, the buckling mode is very simple, all buckling in the direction, if the two-way seismic load is considered, the structure will undergo torsional buckling.

Non-linear analysis of the whole process includes geometric nonlinearity, material nonlinearity and state nonlinearity, while nonlinear buckling analysis is only a part of the whole process analysis. Here we mainly consider the bi-linear buckling of geometry and material. The load factor obtained from the analysis is shown in Figure 3.
Figure 3. Load factor variation graph

As can be seen from the above figure, the maximum displacement when considering nonlinear buckling is the load coefficient curve of the structure; it becomes flat from step 18, indicating that the structure is close to the ultimate load at this time; the calculation results are difficult to converge, and the program is automatically reduced Calculate the time step to meet the convergence of the result. Without the initial defect, with the increase of the vertical load, the node displacement gradually increases, but the corresponding absolute value is smaller. When the structural support column reaches the ultimate bearing capacity, the joint displacement gradually increases to a certain value and remains unchanged. At this time, the joint model has lost the bearing capacity and reached the critical state value.

4. Conclusion
At present, there are few research on the stability of steel frames. In this paper, the beam end supporting conditions of steel frame nodes are regarded as elastic supports, and the energy method and finite element analysis methods are used to study the overall stability of steel frame beams under various load conditions. The article verifies the performance of the proposed BIM-based node stability analysis method only through the structural node model and an actual project, and the results are good, which can effectively reduce the conservative ultimate bearing capacity of the fabricated high-rise steel structure. Calculation amount and calculation time. When the horizontal load is increased, the horizontal displacement of the structure occurs, and with the continuous increase of the load, the corresponding horizontal displacement of the node gradually shows a linear increase trend until it reaches the limit state. The research results of the article have great application value and guiding significance for the construction of prefabricated high-rise structures.

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