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Buckling bearing capacity analysis of section steel with initial defects

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Abstract: Cold-formed steel is the main material of steel structure. Under the action of vertical load and earthquake, it is mainly subjected to compression failure and instability failure. The nonlinear factors of section steel mainly include the following types: geometric nonlinearity, material nonlinearity, initial geometric imperfection, warpage, bending and residual stress effect, local buckling of members, bending torsion buckling, shear deformation, and node semi-rigid. This paper is based on the finite element software ABAQUS. This study contrasts three kinds of working conditions, that is no consideration of initial defects, only considering the initial defect of first order mode and initial two order modes of initial defects.
Keywords: Buckling bearing capacity; steel section; ABAQUS; initial defects

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1. INTRODUCTION

With the accelerated development of China's steel industry and steel structure and other related industries, the demand for cold-formed steel is also increasing. China's cold formed steel is facing a new development climax. Cold bending steel products are applied in the fields of bridge, construction, machinery, transportation, petrochemical, electronics and other industrial fields. In housing construction, cold bending steel can be used as cold-formed steel beams and columns, steel truss, bearing components, also be used as roof panel, wall panels, floor purlin, stress mechanism and retaining structure. Cold bending steel is a kind of steel strip or steel plate bending into various sections of different sections through roll or stamping at normal temperature. The cold-formed thin-walled steel members are prone to buckling due to their thin wall, wide thickness ratio, complex cross-section and mostly open section, and there are many kinds of buckling modes. Generally speaking, there are three buckling modes of partial buckling, full section distortional buckling and integral buckling of open thin-walled members. Under certain conditions, there will also be three kinds of buckling modes. However, due to the production process and construction error, some initial defects will inevitably occur, which will reduce the yield bearing capacity of the steel. This paper introduces the buckling load capacity of common H steel under three working conditions that is: without considering initial defects, considering only one initial buckling mode initial defect and the first two order buckling mode initial defect.

2. MODEL OVERVIEW

The steel used in this paper is H shaped steel, the length of the steel is 2m, and the steel used is Q235. The yield strength of steel Q235 is eaqul to 235MPa and the limit strength of the steel is equal to 420MPa. The size of the section is shown in Figure 1. The finite element software ABAQUS is used to set up the analysis model for numerical simulation. The rod parts are Beam element, and the steel constitutive model adopts the double fold line strengthening model. The bottom of the rod is considered at the fixed end, the top is free and the vertical load is borne. The finite element model is set up as shown in Figure 2.

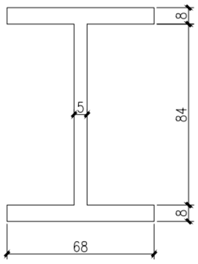


Fig.1 Section steel

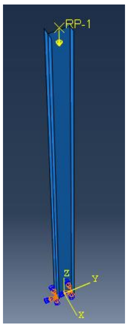


Fig.2 Finite element model of steel column

3. ANALYSIS OF BUCKLING MODE

Cold-formed thin-walled steel structures are widely used in architectural structures, and instability of the structure is becoming more and more common. When a load reaches a critical value, with a small increment, the equilibrium form of the structure changes considerably, which is called structural buckling or structural instability. According to its properties, it can be divided into the following three categories: balance basin instability, limit point instability and jump instability.

In the step analysis of the ABAQUS finite element software, the flexion modal analysis of the rod is selected by buckle. Three kinds of solvers for extracting eigenvalues are provided in ABAQUS, that is : solver of AMS（automatic multi-level substructuring）,Lanczos eigenvalue solver and subspace iterative solver。The AMS eigenvalue solver is a highly efficient extraction solver for large-scale problems. For the simple structure, the subspace iterative solver has high computation accuracy and fast solution speed. Therefore, the subspace iterative solver is applied to solve the eigenvalue problem. The first fourth order buckling mode of the obtained rod is shown in Figure 3.

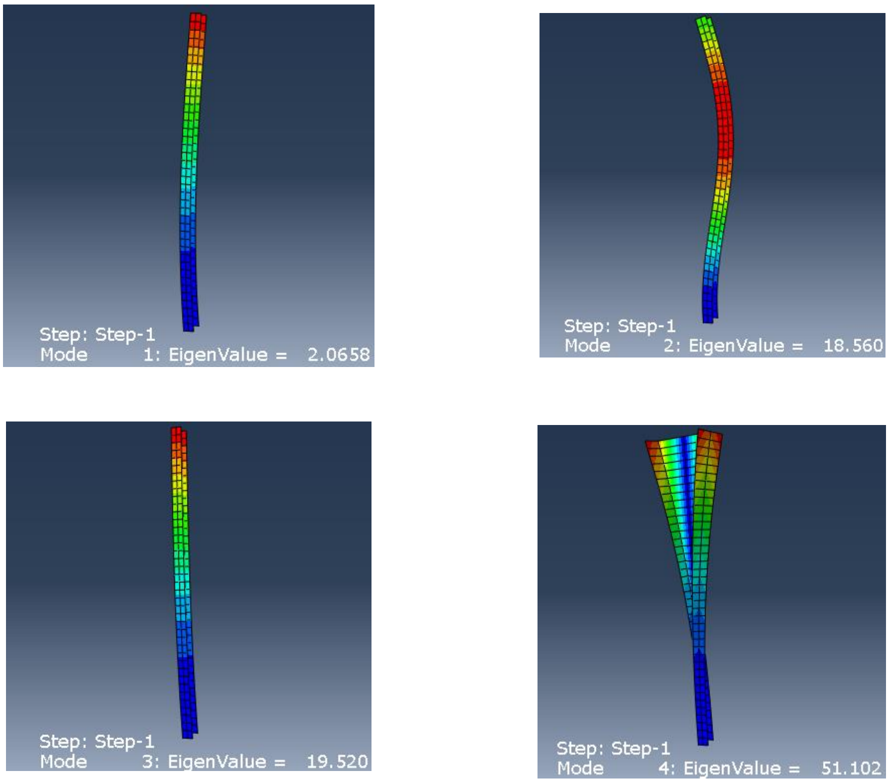


Fig.3 Buckling modes

4. ANALYSIS OF INITIAL DEFECTS

With the development of science and technology, the computing power of the computer is increasing, and the nonlinear analysis of the numerical model can be carried out accurately through the existing technology. The nonlinear factors of section steel mainly include the following types: geometric nonlinearity, material nonlinearity, initial geometric imperfection, warpage, bending and residual stress effect, local buckling of members, bending torsion buckling, shear deformation, and node semi-rigid. This paper focuses on the effects of nonlinear factors such as the geometric nonlinearity of the rod, the nonlinearity of the steel material and the initial defects on the buckling bearing capacity of the structure.

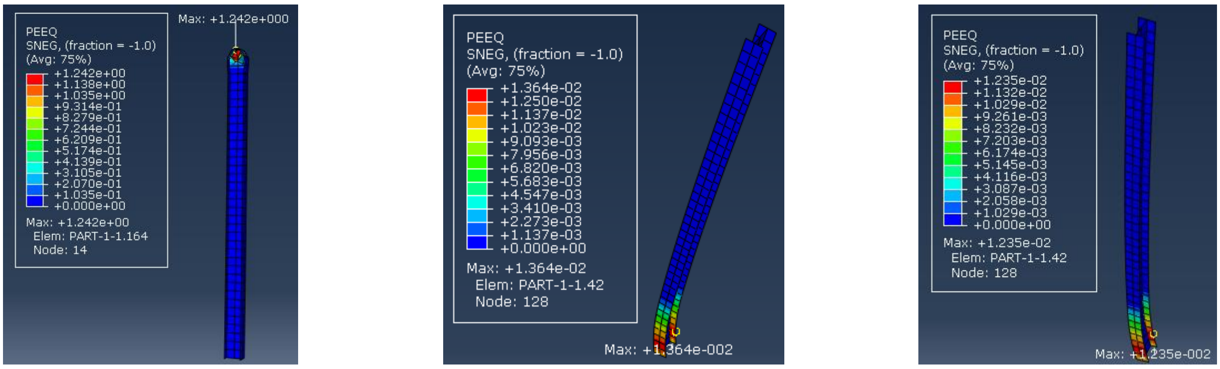
In the step analysis step of ABAQUS finite element software, NLGEOM=on is chosen to consider the geometric nonlinearity of the rod. The nonlinearity of the material is considered by defining the yield parameters in the property module. In this paper, the original defects, such as the residual stress defect and the initial deformation of the rod, are introduced by the uniform defect mode method.

In this paper, the contrast analysis of the initial defects is carried out in the 3 conditions shown in Table 1.

Table 1.Condition types

condition type	condition 1	condition 2	condition 3
features	No consideration of initial defects	Only first order initial defect is introduced	Introduction of first two order initial defects

The development of plastic strain under the vertical load of the three operating conditions is shown in Figure 4. The relationship between the vertical axis force and the horizontal displacement in the bottom of the rod is shown in Figure 5.



No.1 condition　No.2 condition　No.3 condition

Fig.4 Plastic strain diagrams under three working conditions

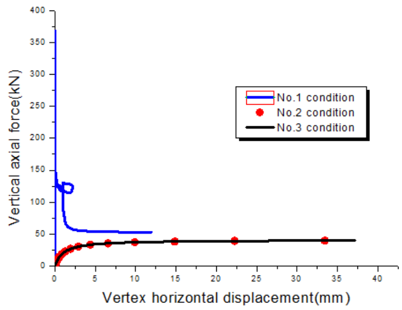


Fig.5 Vertical axial force - vertex horizontal displacement

5. CONCLUSION

The results shown in Figure 4 and figure 5 obtained from the introduction of a rod to the initial defect can be seen as follows:

When the initial defect is not considered, the failure mode of the member is subjected to compression failure, and the failure mode of the rod is buckling failure when considering the initial defect.

For a single compression bar, there is little difference between the vertical axial force and the horizontal displacement of the bottom of the rod at the bottom of the condition 2 and the condition 3. The error is basically negligible. Therefore, in the process of structural design and finite element analysis, in order to simplify the calculation, only the first order buckling mode of the rod is considered as the initial defect.

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