Stability Analysis of a Simple-Supported Bridge with Steel Truss Structure Based on Abaqus Software

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Abstract. With the continuous development and improvement of modern bridge construction technology, the bridge based on steel structure materials has gradually become the mainstream. It is not difficult to find that steel structure has good comprehensive performance and significant advantages compared with other materials, so it can be widely used. In order to explore the stability of steel structure in different states, this paper selected steel truss bridge as the research object. At the same time, the structure of simply supported bridge is selected as the main analysis structure, by using Abaqus modeling software to establish a finite element model and to analyze the overall stability under the most unfavorable load. The analysis and integration of the finite element simulation results show that the stress of the truss under the most adverse load is concentrated in the upper chord. According to the horizontal displacement nebulae, the horizontal displacement of the lower chord is the most serious, and the node is also affected. This experiment can provide a certain reference for the actual design and construction of simply supported bridge with steel structure as the main, and can make a certain deal with the load situation mentioned in this paper.

Keywords: Abaqus modeling; simple-supported bridge; stability analysis.

1. Introduction

In recent years, the development trend of bridges is moving towards lightness and high strength. Under such a development background and concept, bridge based on truss structure was designed and applied. Steel joist is a joist made of steel material, and is widely used as the main element of load-bearing structure in industrial and civil buildings. Due to factors such as the price of steel structure materials and high maintenance costs, steel truss bridges are rarely used in the highway field. In recent years, with the improvement of China's steelmaking technology, steel quality and structural anti-corrosion technology have been continuously improved. Steel bridges are increasingly used in the field of highway engineering [1]. However, steel joist has good seismic resistance, homogeneity and high strength. The characteristics mentioned above can give full play to its mechanical properties during the construction process. It is precisely because of the above characteristics. The application of steel structure has also become the trend of bridge construction in the future [2].

The beam rigid plate bridge has the characteristics of simple structure, light weight and simple support. And it has the characteristics of strong leapfrogging ability, economical steel consumption, convenient construction and good landscape [3]. It has been used in developed countries such as Japan and the USA. The Yodogawa Bridge in Osaka, Japan, built in 1926, and the Pony Truss Bridge in Ohio, USA, which is the prototype of the structure studied here, are examples of simple girder steel plate bridges that are still in use today. Likewise, because the under-bearing steel truss has light weight, strong spanning capacity and building height small and fast construction speed [4]. The simple branch bridge structure is also widely used in China. For example, the Nanjing Yangtze River Bridge is designed by using part of the simple branch bridge structure. Wuhan Yangtze River Bridge not only uses the design method of simple branch bridge structure, but also adopts double-layer steel truss structure. The upper layer is a highway bridge, and the lower layer is a Beijing-Guangzhou railway double line due to empty stomach structure of steel truss structure. As it has good adaptability to the double-layer bridge deck. Steel truss bridges are widely used because of their strong span capacity, fast construction speed, high bearing capacity and good durability [5]. Similarly, with the development of rail transit, the application of steel truss bridge has gradually increased a lot. For example, Chongqing Chaotianmen Yangtze River Bridge, Caiyuanba Yangtze River Bridge and Zengjiayan Jialing River Bridge are all dual-purpose bridges [6].

By studying and analyzing the shape and internal truss structure of pony truss bridge, this paper refers to the model structure and truss connection method of pony truss bridge, so as to provide a foundation for the subsequent Abaqus modeling and determine its feasibility. For space truss structures such as Pony truss Bridges, Kong et al. proposed a practical optimization method for structural stability, which is of great help to the subsequent inference of structural stability ultimate load in this paper [7]. At the same time, regarding the influence level of the stability of truss bridge, this paper refers to the analysis of the stability of long-span steel truss girder arch bridge by Ke et al., mainly from the Angle of sagittal span ratio, suspender fracture and other factors, and fully discusses the stability of the truss structure [8]. In the stability analysis of steel truss structure, Zhou et al. introduced the application of wind load on pipe truss structure by establishing geometric analysis model against the background of practical engineering long-span pipe truss structure. Judging whether the whole is stable and whether the structural force is reasonable from two aspects of linear buckling analysis and joint strength provides further reference for the engineering design, analysis and calculation of this paper, which has practical engineering significance [9].

In this paper, steel truss bridge is selected as the research object, and simple support bridge is used as the main analysis structure. Specifically, the ultimate load coefficient of the truss is based on the span. The finite element model is mainly established and analyzed by using Abaqus modeling software. At the same time, it provides a certain reference for the actual design and construction of simple support bridge based on steel truss structure.

2. Research Methodology

2.1. Engineering Backgrond

The Ohio Pony Truss Bridge in the United States is shown in Fig. 1. The deck is asphalt-filled corrugated metal and is supported by seven W12x30 stringers supported by W24x94 floor beams. Among them, the main research object is the structures on both sides of the truss bridge. The steel size of the string rod is W12*50, and the steel size of the belly rod is W12*26. The dimension parameters of the model components are shown in Table 1. The truss consists of five panels, each 13.20ft long. At its deepest point, the height of the top to bottom string truss is 7.50ft. Laterally, the trusses are spaced 25.53ft apart. The length of the floor beams is equal to the spacing of the trusses, which is 26.56ft. All the steel of the bridge is grade A588, F = 50ksi, Fu = 70ksi.

Fig. 1 Pony Truss Bridge [10]

Table 1. Dimension parameters of model components [10]

Component type	H	B	b_1	b_2
W12*26	310	165	5.8	9.7
W12*50	310	205	9.4	16..3

*Note: H is the height of the web, B is the width of the flange plate, b1 is the thickness of the web plate, and b2 is the thickness of the flange plate.

2.2. Abaqus Finite Element Model

According to the characteristics of the engineering background, this paper uses Abaqus finite element software to simulate the finite element of the Pony Truss Bridge. This model adopts 2D linear basic modeling, and defines the section of the truss by defining the profile content. Its purpose is to simplify the modeling process and facilitate subsequent analysis of model calculation results. The two ends of the structure are hinged supports, and the load of the middle four nodes is F=83938N, as shown in Fig 2.

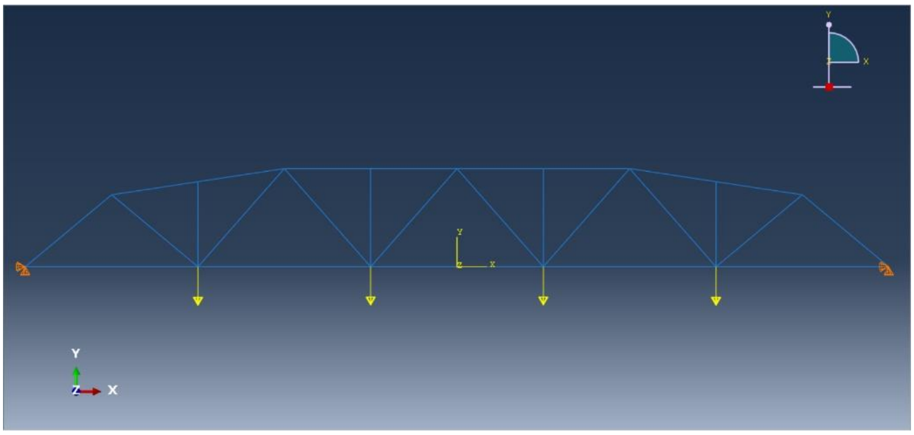

Fig. 2 Schematic diagram of finite element model loading (Photo credit: Original)

Then, the model is meshed and defined, and for the convenience of model calculation and reasonable meshing, the overall model element is defined as beam element. The finer units are divided into quantities, which are set at 1. Finally, mesh is carried out, the finite element model of the pony truss bridge is obtained, as shown in Fig. 3.

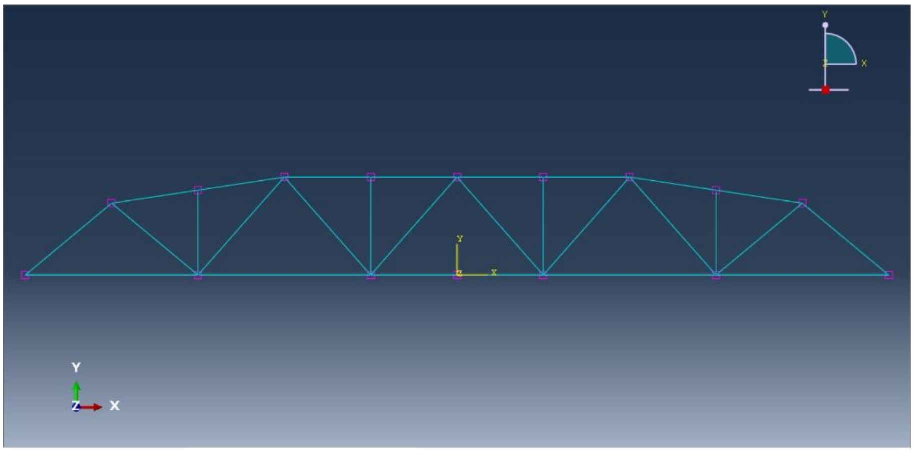

Fig. 3 Finite element model of pony truss bridge (Photo credit: Original)

3. Results and Discussion

3.1. Finite Element Model Results

By loading the finite element model, the stress cloud is obtained as shown in Fig. 4. The analysis in Fig. 4 shows that the upper chords are subjected to high stresses and are prone to local buckling. There is almost no stress in the belly bar, and some parts of the lower chord bar have slight stress, without considering the damage situation.

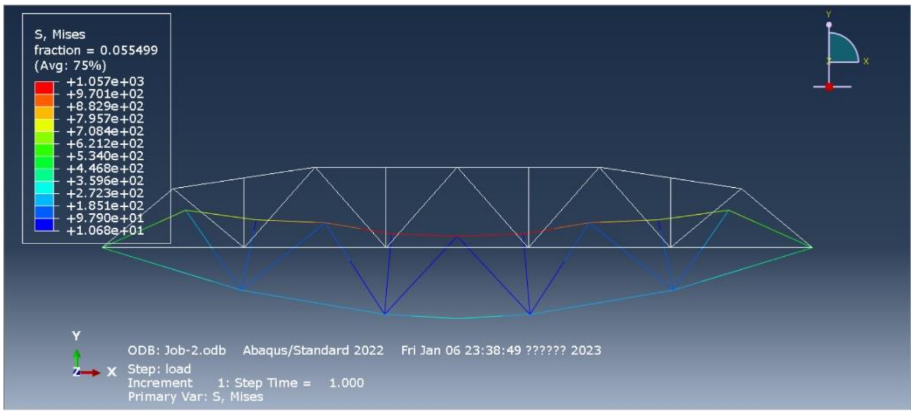

Fig. 4 Stress nephogram of the model after loading (Photo credit: Original)

Fig. 5 shows the horizontal displacement cloud image of the model after loading. It can be seen from Fig. 5 that the horizontal displacement of the truss member has a certain correlation with its tensile strength. In this structure, the horizontal displacements of the individual rod units in the structure should be considered for the truss structure under the most unfavourable loading.

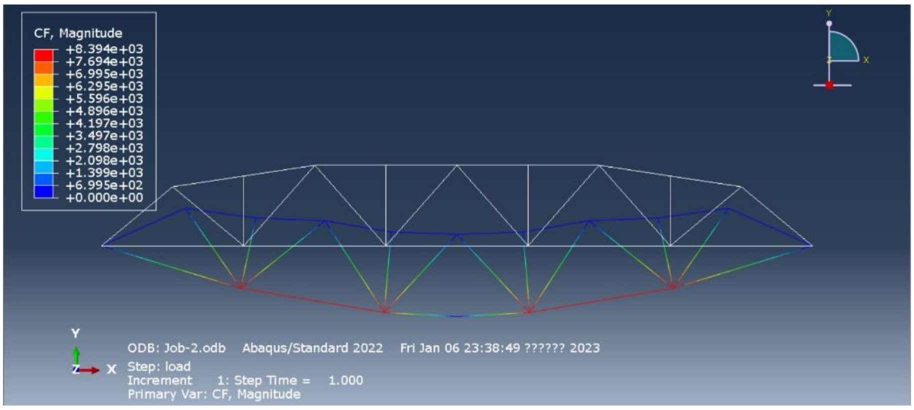

Fig. 5 Horizontal displacement cloud of the model after loading (Photo credit: Original)

3.2. Discussion

According to the results of the model, the greatest stresses are in the middle of the span of the upper chord, while the greatest horizontal displacements are in the second and fourth spans of the lower chord. In the same vein, the values of horizontal displacements are generally greater than the values of stresses. The treatment of the lower chord should therefore take precedence over the upper chord and needs to be given priority in the design. Also due to the stress situation of the bars, additional thought needs to be given to the strength of the nodes, and in the case of bar unit deformation, enhancing the strength of the nodes should also be included in the consideration of the structural design.

It is difficult for long-span truss structures to ensure the stability of the overall structure under the action of external forces, and the local buckling of the structure is easy to occur to the overall instability under the action of long-term load, so it is very important to analyze the buckling stability. The design can be based on the specific stress of the structure of the structure of a component for processing, can increase the local stability of a member, so as to improve the overall stability of the structure.

4. Conclusion

In this paper, the truss bridge is taken as the research object, and the following conclusions are obtained through modeling analysis.

(1) The stress cloud calculated by linear buckling analysis shows that the truss stress under the most unfavorable load case is concentrated in the upper chord. The upper chord should be treated with special treatment during bridge construction to cope with possible local instability.

(2) Through modeling analysis, the obtained horizontal displacement cloud can be seen that the horizontal displacement of the lower chord is the most serious, and the node is also affected by the horizontal displacement, so that the node processing priority at the lower chord should be the same as that of the lower chord.

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