Static and dynamic analysis of a kind of special suspension bridge

Weiquan Fan [1], Chang Liu [1], Chunyang Yang [1] and Yulong He [2,*]

[1]School of Architecture and Construction, Xijing University, Xi'an 710123, China

[2]School of Transportation, Jilin University, Changchun 130022, China.

Corresponding author:heyl15@mails.jlu.edu.cn

Abstract

To study the static and dynamic performance of the suspension bridge deck, the 10 m + 80 m + 10 m deck suspension bridge finite element model is established using the finite element analysis software ansys12.1 , and the modal analysis of the bridge is carried out. The internal force characteristics of the suspension bridge are obtained. Through the modal analysis, the dynamic characteristics of the self vibration frequency, the self vibration period and the vibration pattern of the bridge structure are obtained. The results of dynamic characteristics analysis show that the main vibration mode of such bridges is very large with the increase of order. The 1 order main vibration mode is vertical bending, and the higher order main vibration modes will also appear lateral displacement and torsion. The conclusions can provide reference for the design and seismic analysis of the upper bearing suspension bridge.

Keywords

Suspension Bridge; Dynamic Characteristics ; Internal Force Analysis.

1. Introduction

The upper bearing suspension bridge is a new type of bridge developed in the late 70s, also known as the reverse suspension bridge.The first deck suspension bridge is the krolado bridge designed by the famous master of structure Lin Tongyan. Because of its low cost, unique shape, fast construction and so on, this kind of bridge has been widely concerned by experts at home and abroad. Such as gold bridge, Liuzhou bridge, Guandu bridge, rail speed peak bridge and bard Sen bridge have adopted a deck type sling system. Some research results have been produced for the design part of the suspension bridge.

However, the internal force analysis and dynamic response (such as wind vibration, earthquake, etc.) to such bridges have not been studied systematically yet, and the dynamic characteristics of bridges are the important foundation for studying the dynamic response of bridges. Therefore, the static and dynamic characteristics of such bridges is very necessary.

2. Computational model

Deck type suspension bridge is composed of bridge deck system, column frame, main cable and sling (bottom) .In this case, referring to the bridge layout of the Colorado Bridge, a 10m + 80m + 10m compound bridge with the above-mentioned suspension sling structure as the main body and combined with the slanting leg rigid structure is adopted. The lowest point of the suspension belt is 15m away from the bottom of the bridge deck.

The bridge slab directly bear the vehicle load or pedestrian load, the main pressure and bending moment. Equivalent to the suspension bridge in the stiffening beam, as the compression member, the bridge deck is generally built using reinforced concrete or prestressed concrete, and the cross section is mostly designed as the form of T beam(Figure 1).As a sub-structure of the column rack, can load the bridge deck load transmitted to the floor, the equivalent of the suspension cable suspension bridge or boom, is the compression member.The column frame is usually built with reinforced concrete, which is often designed as a door type structure(Figure 2).

The main suspension belt is the main force component. The vertical load of the whole bridge is borne by the main cable. The main cable is mainly subjected to the tensile force, giving full play to the tensile properties of the steel, which is equivalent to the main cable of the suspension bridge. Suspended with concrete wrapped main cable, to withstand stretching and bending.Generally, the high strength steel wire is woven into multiple groups of parallel beams and arranged under the column frame.

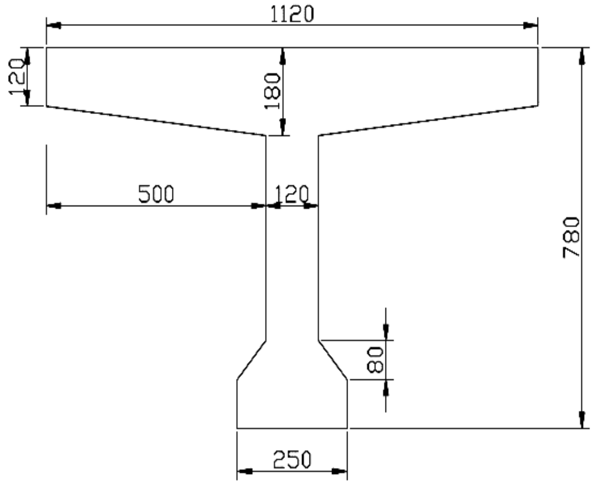


Figure 1 Cross section diagram of T beam

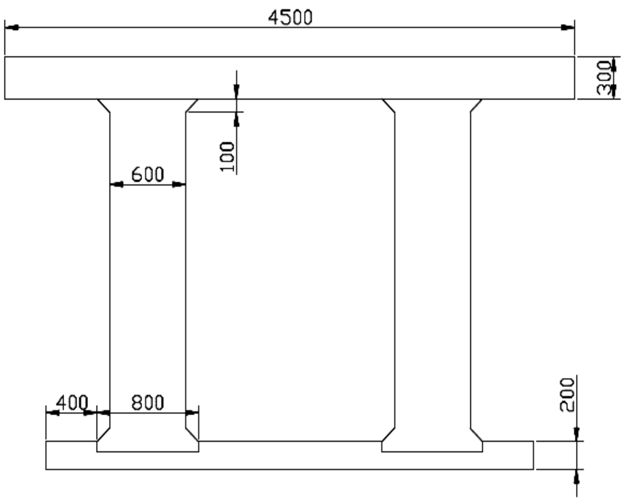


Figure 2 cross section diagram of column frame

The finite element model is established for the bridge. The beam element in the material library is used to simplify the model. The girder and the column beam are simplified by the corresponding rectangular cross-section according to the principle of equivalent bulk density and equivalent stiffness. The finite element calculation model shown in Figure 3. After the model is established, the grids are divided and imposed, and the ends of the inclined legs are fixed-end treated. The main girder is treated according to the simply supported girder constraint, and exerts the self-weight effect on the girder.

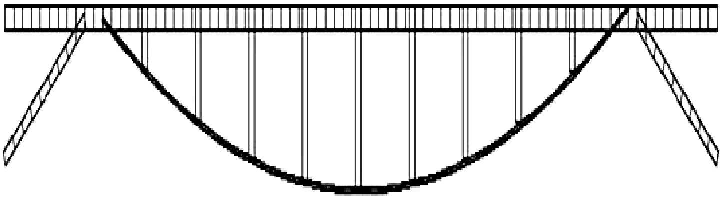


Figure 3 Full-bridge finite element model

3. Calculation results

3.1 Static analysis

According to the static calculation results, compared with the normal slant-legged rigid-frame bridge, the bending moment of the cross-structure is obviously reduced due to the vertical column, which increases the span-ability of the bridge. However, a large bending moment still appears at the rigid connection of the leg.

This type of bridge is an anti-hanging structure. Contrary to the larger horizontal thrust in a normal arch structure, the horizontal pressure appears on such a bridge. The bridge deck body can be balanced as a compression rod to save a set of force components.

3.2 Dynamic characteristics

Vibration mode is inherent in the elastic structure, the vibration characteristics, the structure of each mode has its own specific frequency, period, damping ratio and mode shape. The analysis of the vibration mode is to transform the physical coordinates in the vibration system of linear steady-state system into the modal coordinates so that the system of equations is decoupled into a group of independent equations described by modal coordinates and modal parameters. In order to find the modal parameters of the system. Modal is the multi-degree-of-freedom structural system into a single-degree-of-freedom structural system of superposition, multi-degree-of-freedom structural system of self-vibration dynamic differential equations such as type 1 .

$$[M]\ddot{\mathbf{y}} + [C]\dot{\mathbf{y}} + [K]\mathbf{y} = \mathbf{0} \quad (1)$$

Where: $[M]$ - structural mass matrix

$[C]$ - Structural damping matrix

$[K]$ -Structural stiffness matrix

$\ddot{\mathbf{y}}$ - Acceleration column vector

$\dot{\mathbf{y}}$ - Speed column vector

$\mathbf{y}$ - Displacement column vector

In actual structural calculation, the influence of damping effect is usually neglected. Therefore, the self-vibration dynamic differential equation of multi-degree-of-freedom structural system that has no damping effect is obtained as shown in Equation 2

$$[M]\ddot{\mathbf{y}} + [K]\mathbf{y} = \mathbf{0} \quad (2)$$

By further transforming the above matrix equation, the matrix equation for calculating the natural frequency of the structure can be obtained (Equation 3)

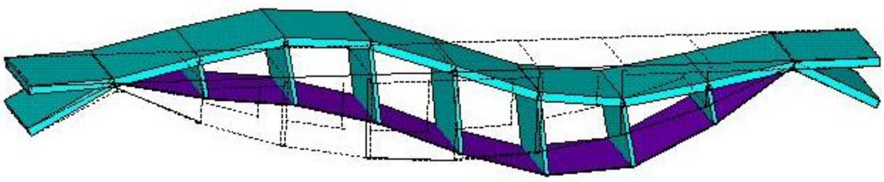
$$[K]\boldsymbol{\varphi} = \omega^2 [M]\boldsymbol{\varphi} \quad (3)$$

In the formula, $\boldsymbol{\varphi}$ indicates the structural mode vector of the structure and ω indicates the natural frequency of the structure. Thus, modal analysis can be used to understand the dynamic characteristics of the structure to predict the actual dynamic response of the structure due to various internal and external vibration sources. Therefore, modal analysis is an important method to obtain the dynamic characteristics of structures and to consider the dynamic response of structures.

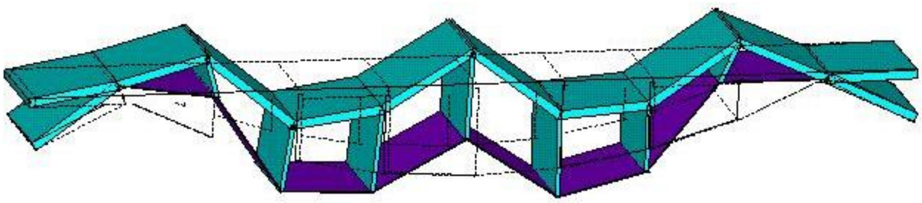
By using the multiple Ritz vector method to analyze the modal analysis of the bridge established above, the dynamic characteristics of natural frequency, natural period and mode shape can be obtained. In this case, a total of 30 modalities are taken, the natural frequencies and natural periods of each mode are listed in Table 1, and the mode shapes of the modes 1, 5, 10, 20 and 30 are selected as shown in Figure 4 Show

Table 1 Bridge natural frequency and period in different modes

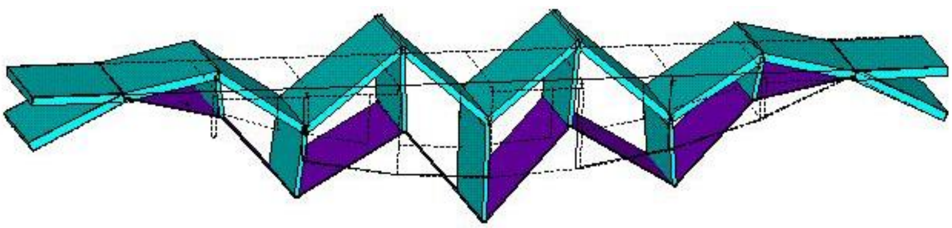
Number	Frequency (Hz)	Period (s)	Number	Frequency (Hz)	Period (s)
1	1.3389	0.746882	16	18.949	0.052773
2	1.8901	0.529073	17	19.903	0.050244
3	2.4821	0.402885	18	21.587	0.046324
4	3.9268	0.25466	19	21.778	0.045918
5	5.6521	0.176925	20	23.249	0.043013
6	6.8854	0.145235	21	27.173	0.036801
7	8.3288	0.120065	22	28.539	0.03504
8	9.8664	0.101354	23	29.636	0.033743
9	9.9532	0.10047	24	29.876	0.033472
10	11.371	0.087943	25	34.277	0.029174
11	12.856	0.077785	26	36.93	0.027078
12	14.315	0.069857	27	42.036	0.023789
13	15.089	0.066273	28	47.896	0.020879
14	15.66	0.063857	29	49.266	0.020298
15	17.367	0.05758	30	54.122	0.018477



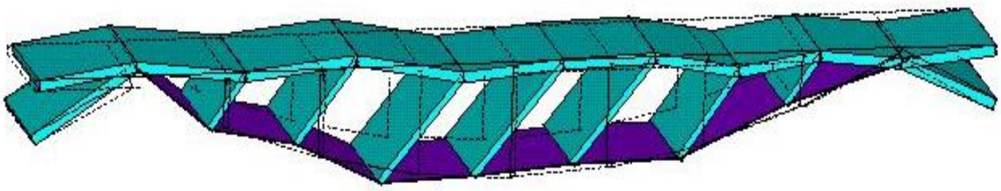
(a) 1



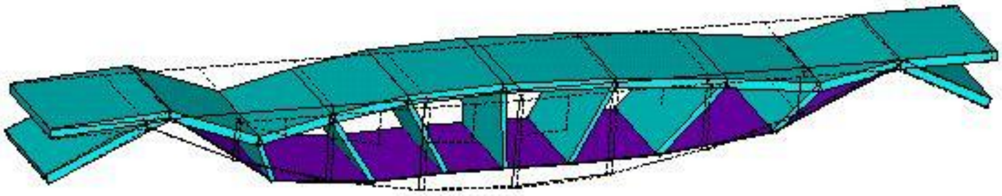
(b) 5



(c) 10



(d) 20



(c) 30

Figure 4 typical vibration pattern of bridge structure

Through the analysis of the vibration mode diagram, the vibration of the slant leg in the first-order vibration mode is not significant, the vibration amplitude of the main structure sling section is large, and the vibration mode shows the inverted S-shaped vertical bending deformation. Because the girder section stiffness is greater than the sling and the column rack, so the main beam vibration amplitude is small, and only vertical vertical bending, did not appear to move longitudinally; while the sling in the first mode both Dramatic vertical bending, along the bridge along the longitudinal swing.

The fifth-order and tenth-order modes are similar in shape, and their main modes are characterized by vertical bending. In the fifth-order vibration, the longitudinal girder has not yet been longitudinally shifted at this time, but the belt has experienced significant longitudinal and lateral displacement. The tenth-order mode changes more than the fifth-order mode. The upper part Beam micro-shift occurs, and the closer to the center of the bridge type vibration ups and downs.

In the twentieth mode shape diagram, the main girder began to appear side-shift and torsional deformation. At this time, the torsion and lateral displacement also occurred in the part of the span-span leg. The vertical bending of the whole bridge became smaller and the deformation was mainly lateral. The thirteenth mode of the structure shows the symmetric lateral displacement torsion. At this time, the main deformation of the structure is mainly lateral displacement and torsion.

4. Conclusion

Finite element analysis of the suspension bridge modal analysis to understand the dynamic characteristics of such bridges, the main conclusions are as follows:

(1) The first 30 natural frequencies and the natural periods of the suspension bridge have a great change, and the natural frequency of the thirtieth order is about 40 times of the first order frequency.

(2) In the same vibration model, the vibration deformation is different due to the different structural cross-section stiffness of each component, and the vibration deformation of the main cable suspension and the column bracket is larger than that of the main beam. Therefore, under the action of a certain force, the main cable suspension and column rack are more vulnerable to damage.

(3) With the increase of natural frequency, the vibration modes of each step have great changes. In the first few modes, the structure is mainly vertical and longitudinal, with the increase of order, Bridge began to appear side shift, torsion and other vibration type.

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