Discussion on Dynamic Characteristics of Extradosed Cable-stayed Bridge

Qian Li[1], Kehai Wang[2], Zhenyu Jiang[3]

Abstract

Extradosed cable-stayed bridge, which also is named partial cable-stayed bridge, is a novel style bridge between girder bridge and cable-stayed bridge. Because of its advantageous structural function, special superiority in economy and architecture etc., more and more extradosed cable-stayed bridges were constructed in the world. However, several definition methods for such bridge have been putting forward, and can not be coincident with each other. In this case, engineers will be confused during design. Otherwise, the amount of this type of existing bridges is still smaller than other bridge types. So it is necessary to study the dynamic characteristics of extradosed cable-stayed bridge in detail to understand the forces and displacements during earthquake.

There such bridges, which are located in Shanxi province and Hebei province respectively, were showed in this paper. Firstly, the parameters for design were provided. And then the dynamic characteristics of these there bridges were analyzed. Finally, dynamic characteristics that can reflect the dynamic response were summarized by reviewing the existing concepts and combining with the results of analysis conducted in the paper. The conclusions are valuable to further study on dynamic properties of extradosed cable-stayed bridges.

Key words: Extradosed cable-stayed bridge, Dynamic Characteristics, Dynamic response, Parameters for design

1. Introduction

Zhangzhou War Preparation Bridge built in 2001 which is the first extradosed cable-stay bridge in China. It has a main span length of 132m and the ratio of side span to main span is 0.612. Because of its special mechanical performance, more than ten such bridges have been building since then. Shihuan Highway Bridge and Xianshenhe Bridge are such bridge. In China, extradosed cable-stay bridges adopt the structural type of deck-tower fixed, deck-tower and pier separated, but these bridges introduced in this paper are unique. First, deck, tower and pier are fixed together that is different from others, and high pier, which is more than one hundred meter, is used in the Xianshenhe Bridge.

1.1 Introduction to Shihuan Highway Bridge

Shihuan Highway Bridge in Hebei is a prestessed concrete extadosed cable-stayed bridge with a low tower and single cable plane. Spans are attributed as (45+85+85+45) m. The structural type is a fixed system, that is, tower, deck and pier are fixed together. The elevation is showed in Fig. 1. The tower is 38.6m in height (cross section is showed in Fig. 2) and the main pier under it is 13m in height. Single box with three room girder is used and the height is 2.5m. Pier 10 and pier 14 are double-column frame piers with four cast-in-site bored piles, and pier 11 and pier 13 are double-column piers with four cast-in-site bored piles also. Bearings are set on the top of the piers except pier 12.

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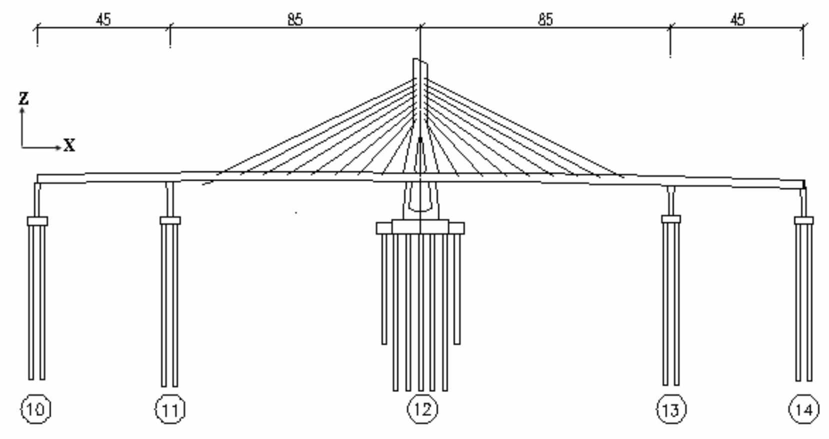


Fig. 1 Elevation of the Shihuan Highway Bridge (units: m)

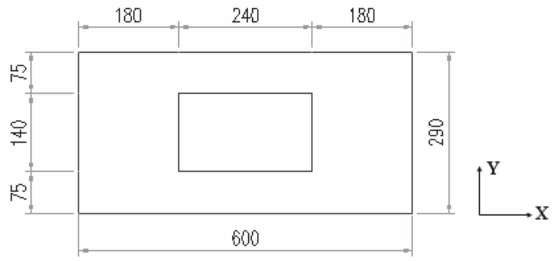


Fig. 2 Section of tower（units: cm）

1.2 Introduction to Xianshenhe Bridge

Xianshenhe Bridge in Shanxi is a prestessed concrete extadosed cable-stayed bridge with a low tower and single cable plane. Spans are attributed as (136+136) m. The structural type is a fixed system, that is, tower, girder and pier are fixed together. The general configuration is showed in Fig. 3. The tower is 49m in height (Fig. 4) and the pier is hollow pier with the height of 151.57m (Fig. 5). Single box with three room girder is used and the height is various. Bearings are set at the abutment only.

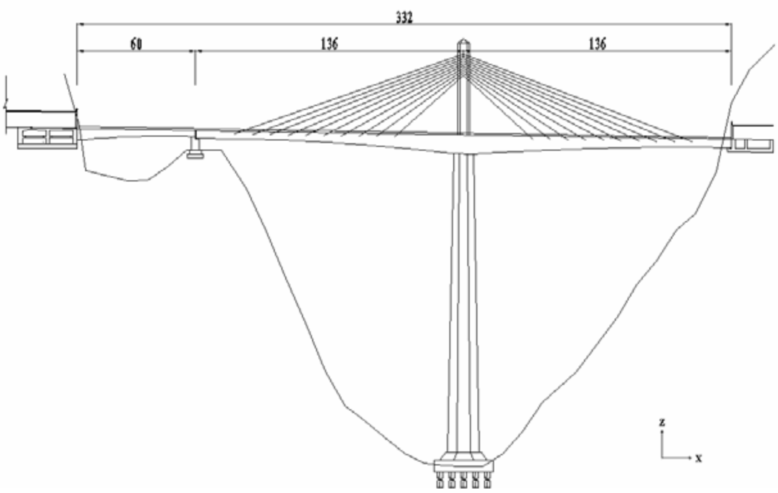


Fig. 3 General configuration (units: m)

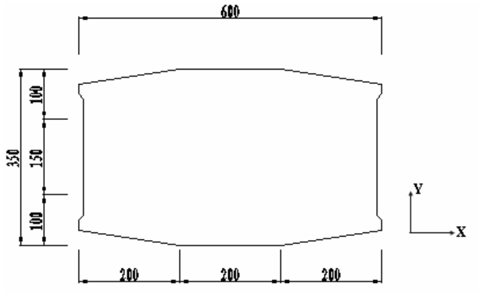


Fig. 4 Section of tower（units: cm）

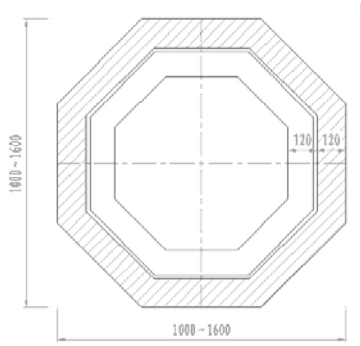


Fig. 5 Section of pier（units: cm）

2. Dynamic Characteristics

2.1 Dynamic Characteristics of Shihuan Highway Bridge

(1) Cumulative effective mass factors

Cumulative effective mass factor in the longitudinal direction converged quickly and achieved90% in the first 11 modes. In another direction, factor achieved satisfying level at 31st mode and 150th mode respectively.

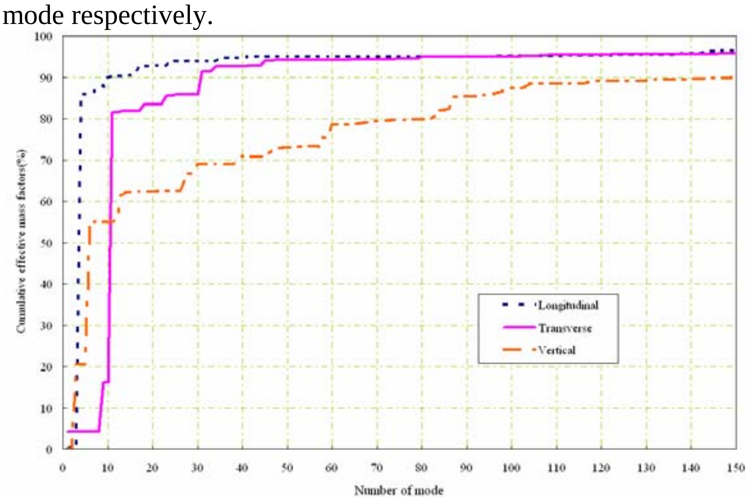
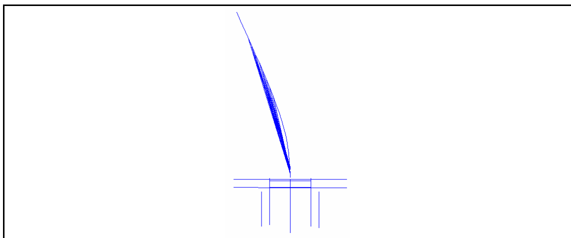


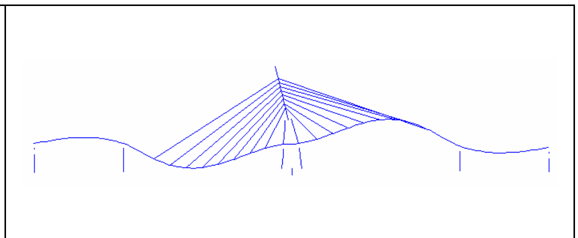
Fig. 6 Cumulative effective mass factors of first 150 modes

(2) Period and mode shape

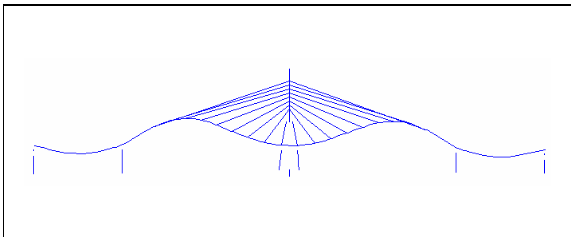
Period and mode shape of Shihuan Highway Bridge were showed below. The basic period was 0.9473 sec, so the bridge belonged to short period structure. The first mode shape was transverse tower mode, that is to say, the tower was more flexible than other part. Symmetrically vertical deck modes, such as 3rd mode, participated to vertical response principally.



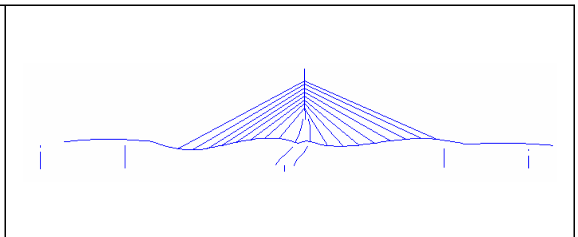
1st mode T=0.9473sec, transverse tower mode



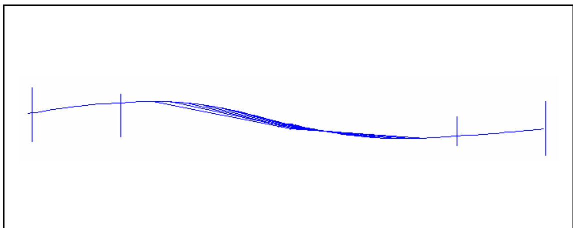
2nd mode T=0.8422 sec, vertical deck mode



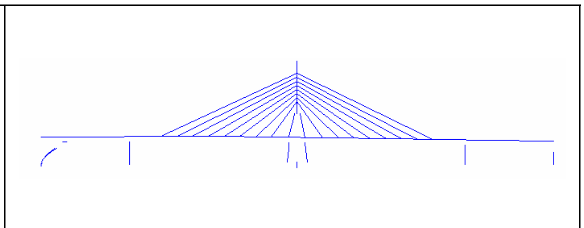
3rd T=0.6594 sec, vertical deck mode



4th T=0.5380 sec, longitudinal mode



9th T=0.3145 sec, transverse deck mode



10th T=0.2755 sec, pier 10 mode

Fig. 7 Partial period and mode shape

2.2 Dynamic Characteristics of Xianshenhe Bridge

(1) Cumulative effective mass factors

Different from Shihuan Highway Bridge, cumulative effective mass factor in three directions converged quickly and almost achieved 90% at the same time.

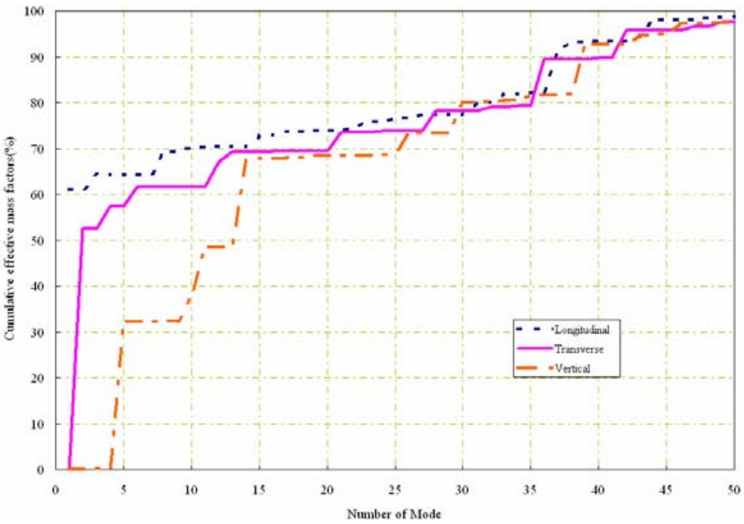
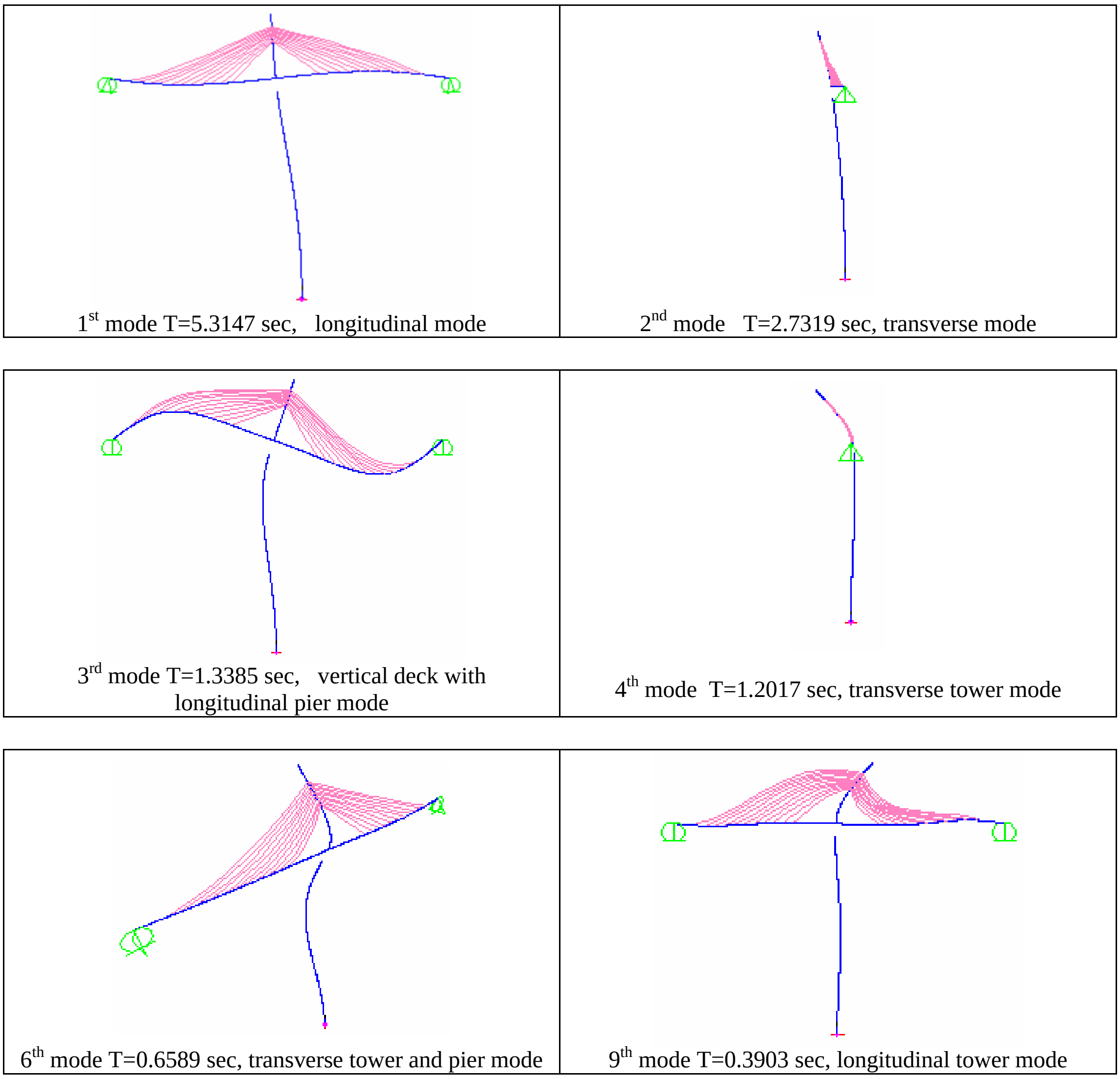


Fig. 8 Cumulative effective mass factors of first 50 modes

(2) Period and mode shape

Period and mode shape of Xianshenhe Bridge were showed below. From the research done before, the basic period of the long-span girder bridge with high pier is from 2sec to 4sec normally. The basic period was 5.3147 sec, which was between that of long-span girder bridge with high pier and normal cable-stayed bridges. Because of the high pier, many pier modes appeared and participated to horizontal response.



1st mode T=5.3147 sec, longitudinal mode

2nd mode T=2.7319 sec, transverse mode

3rd mode T=1.3385 sec, vertical deck with longitudinal pier mode

4th mode T=1.2017 sec, transverse tower mode

6th mode T=0.6589 sec, transverse tower and pier mode

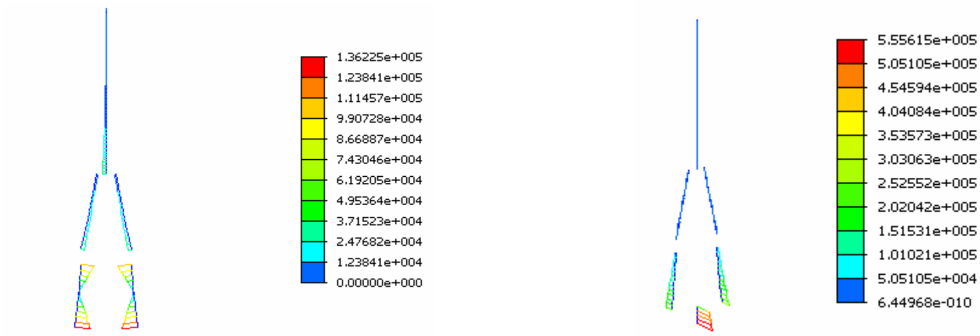
9th mode T=0.3903 sec, longitudinal tower mode

Fig. 9 Partial period and mode shape

3. Dynamic Response

3.1 Dynamic Response of Shihuan Highway Bridge

When the earthquake happened, the moment in the tower and pier was show in Fig. 10, and because of the structure was short period, displacement in horizontal plane was about 1cm, so the seismic demand to bearing was low, which is distinct from those normal cable-stayed bridges.

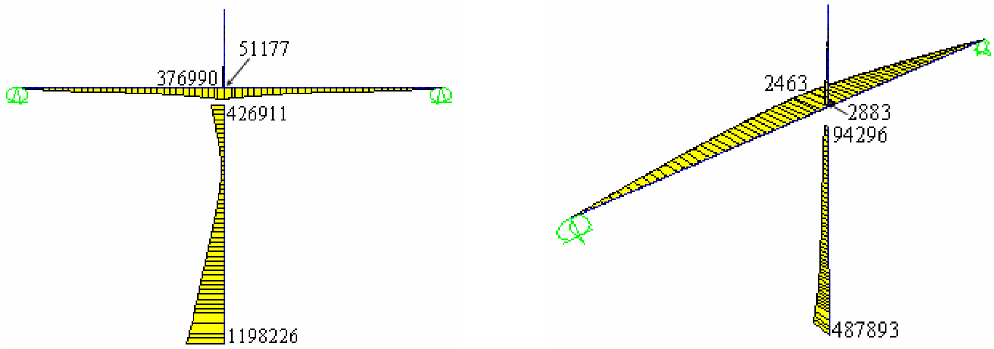


Longitudinal moment (PHA=0.1g) Transverse moment (PHA=0.1g)

Fig. 10 Diagram for moment

3.2 Dynamic Response of Xianshenhe Bridge

When the earthquake happened, the moment in the tower and pier was show in Fig. 11. Because the structure was long period structure, displacement in horizontal plane was larger than Shihuan Highway Bridge, and the maximum horizontal displacement was 19.8cm, so the seismic demand to bearing was higher, but which was still lower than that of normal cable-stayed bridges.



Longitudinal moment (PHA=0.1g) Transverse moment (PHA=0.1g)

Fig. 11 Diagram for moment

4. Conclusions

Forenamed dynamic analysis indicated that extradosed cable-stayed bridge was different from the normal cable-stayed bridge. The basic period of the extradosed cable-stayed bridge was shorter than cable-stayed bridge and if the main pier was not too high, the basic period maybe shorter than long-span girder bridge with high piers. So most extradosed cable-stayed bridges were short period structure, and the seismic demand for bearing would be small, the deformation capacity of bearing would be satisfied the requirement easily. It was noticed that extradosed cable-stayed bridge with high pier such as Xianshenhe Bridge was especial, and pier mode would participate to the earthquake response. Just because of the flexibility of high pier, the basic period could be extended, and the displacement would be large.

Acknowledgement

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5. References

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