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ONE PEDESTRIAN SUSPENSION BRIDGE WITH SPATIAL UNILATERAL HANGERS AND TWIN CURVED DECKS IN SHANGHAI

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Summary

One of two pedestrian suspension bridges with twin curved decks suspended by spatial unilateral hangers is described in detail. It was built in Shanghai international tourism resort, which is 120m long in total and composed of an outer main deck with 6m width and an inside auxiliary deck of 3m wide. Steel box girder of main deck was fixed by two tensile bears at the abutments to resist torsion, and inclined steel-pipe piles were adopted for foundations of pylons and abutments to balance horizontal thrust for soft ground. The structure system and mechanical property was assured by analysis. To meet human-walking comfortability, TMD damping devices were employed for the bridge.

Keywords: twin curved decks; unilateral hangers; pedestrian; suspension bridge; TMD; inclined pile.

1. Introduction

Shanghai Disneyland Park is the sixth one in the world. Wishing Star Lake, located in the southeast of the Park，is an important part of its transportation and landscape. Two pedestrian bridges, scheduled in the southeast and southwest of the lake, became the focus of landscape. These two bridges are composed of an outer main deck with 6m width and an inside auxiliary deck of 3m wide, while the maximum total width of 11.6m with 2.6m gap in the mid-span. Because of different start height and slope, there is a crescent-shaped space between the main deck and the auxiliary deck, which makes a very complicated deck system. The east bridge is 120m long in total, and the west one 90m. In this paper, limit the study to the east bridge only.

2. Structure Design

The bridge structure system consists of twin decks, main cables, annular cable, hangers, backstays, radial cables, etc.，as well as pylon towers and abutments. The outer deck is a steel box girder, and its end torsion is constraint at the abutments. The outside of the girder is unilaterally suspended by spatial hangers connected to the main cables, which are supported by two pylons and anchors. Two back cables are arranged on the top of the pylons to balance the tension of the main cables. The inside glass auxiliary deck is connected to the main deck through Y-shaped components and is balanced by the horizontal annular cable. To increase the rotation rigidity of inside deck, it is connected the main girder by radial cables.

Cables are composed of high strength steel wires of 1560Mpa, sealed by GLFAN (95% Zn +5% Al) coating, which has good ductility and anti-sliding ability. The main cable and annular cable adopted "Z" type enclosed cable to promote durability and aesthetics, and anchorage of cable adopts hot-cast anchor to reduce its size.The outer deck is a steel box beam which is 1.7m height and 6m width. Diaphragms are set each 3.73m to prevent distortion. As width of the deck is very large, torsion effect is difficult to be completely balanced through hangers and horizontal annular cable. Steel box beam is adopted for main deck to increase torsion resistance and its end torsion is fixed at the abutments by two vertical tension bears. The inner deck consists of Y-shaped components which are connected together in plane by two side I-beams. Cross tension bars are added for each two spacing to increase plane stability. Y-shaped components are hinged with the box girder

allowing vertically rotation and small rotation along the bridge. Lower ends of Y-shaped component are hinged on the annular cable, and are connected with the box girder by radical cables.The pylon tower is a circle tube of 20m high, with diameter of 900mm and thickness of 40mm. Inclined angle of 12 degree is used to improve the stiffness of the pylon against horizontal forces. The lower end of the pylon is hinged with the concrete base. At the top of the pylon, the main cable and the back cables are hinged with ear plates Due to the main cable and unilateral hangers, large horizontal thrust acts on pylon bases and abutments. As horizontal bearing capacity of piles is very small on soft ground, inclined piles provide reliable horizontal bearing capacity. Based on the existing pile-sinking equipment, the inclined angle of piles can be realized with 12 degree. The piles is of 35m long with 900mm diameter.

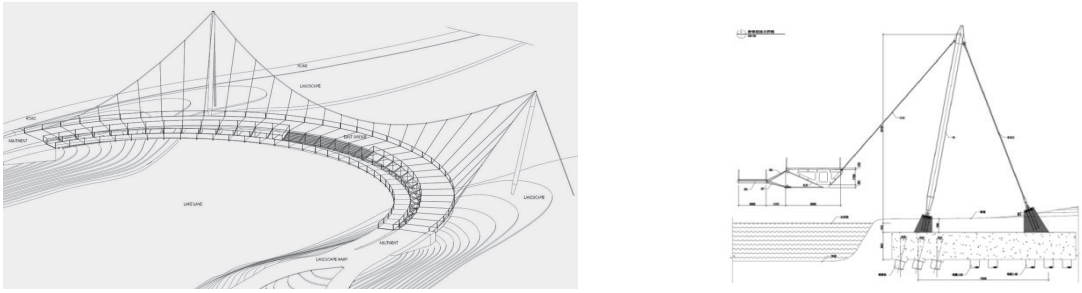

Fig.1 General arrangement plan, a) 3-D view; b) Transverse view

3. Structural Analysis and Test

Effects of static loads were considered and the structure had enough stiffness, strength and stability. Time-history analysis of earthquake was carried out, which showed that the structures were within the elastic range. The numerical wind tunnel simulation showed that the wind load had little influence on the internal forces of the structure, but had certain influence on the displacement. The vertical acceleration at some positions could be large. Wire mesh fence was adopted instead of glass railing to reduce wind resistance.As its large span, the first frequency is 1.3Hz and the second is1.62Hz for girder vertical vibration, which is sensitive to pedestrian. For steel box assumed damping ratio to be 0.5%, modal vibration induced by pedestrian was analysed for the second mode of vertical vibration. For moderate human-density or above comfortability cannot meet requirement. TMD damping devices were employed for the bridge at 1/4 and 3/4 span of box girder and at 1/2 span of auxiliary deck. Then for very dense condition, comfortability is fine.

Static and dynamic loading tests for the bridges were carried out after completion. The results showed that the deformation and internal forces were all within the allowable error. The dynamic load tests included the determination of the dynamic characteristics and vibration response with or without TMD damping devices.

4. Discussion and Conclusions

From 1970’s, a large number of unilateral suspension curve bridges have been built in Europe and America. Different from those bridges, both of unilateral suspension bridges in Shanghai are wider and have twin decks. Steel box girder was adopted with end fixed for increasing torsion resistance, TMD controllers were provided to improve comfortability, and inclined steel-pipe piles were used to resist horizontal force in soft soil ground. Although this type of bridge had never practised before in China, it was completed satisfactorily.

5. Acknowledgements

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6. References

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