Rigidity Selection for Mid-Tower of Three Tower Suspension Bridge

Jing RUAN
Bridge Engineer
J.P.C.D.
Taizhou, CHINA
ruanjing@yahoo.com

Ruan Jing, born 1975, received her BS and MS from South East Univ.

Zhaoxiang FENG
Bridge Engineer
J.P.C.D
Taizhou, CHINA
tzbridge@163.com

Feng Zhaoxiang, born 1968, received his MS and PhD from Hohai Univ.

Jianchi ZHONG
Director
J.P.C.D
Taizhou, CHINA
tzbridge@163.com

Zhong Jianchi, born 1957, received his BS from Hohai Univ.

Summary

Comparing with normal two-tower suspension bridges, the whole stiffness of three-tower suspension bridges are relatively small， while the ratios of the deflection to span of these structures are larger. The mid-tower stiffness of three-tower suspension bridge has great influence on the mechanical behaviour of the whole bridge due to inner characteristics of this kind of bridges. Basing on some model experiments and related design specification, some design restrictions of three-tower suspension bridge, such as the deflection of the main span and the anti-slipping safety factor between the main cable and saddle of the mid-tower, are presented. Considering these practical restrictions and analytical results on the influence of the stiffness of the mid-tower to the whole structures, the paper shows the reasonable range of mid-tower stiffness. A proper structural style satisfying all of these restrictions is proposed at the end of this paper.

Keywords: three-tower suspension bridges; rigidity selection; anti-slipping safety factor; deflection of the main span.

1. Introduction

Due to the needs of transport facilities across rivers and seas, some ultra long span bridges have been developed rapidly. Multi-tower suspension bridge’s ultra long spanning ability obtains engineers attention. Considering the navigation capacity and the utilization of waterfront resources in the Yangtze River, china’s taizhou Yangtze River Bridge has ultimately chosen a three-tower two-main-span suspension bridge. Basing on the project, we study the influence of the mid-tower rigidity to the whole structures with finite element method, present some design restrictions of three-tower suspension bridge, then, show a reasonable range of mid-tower stiffness and propose a proper structural style satisfying all of the restrictions at last.

2. Influence of Mid-Tower Rigidity on Its Structure

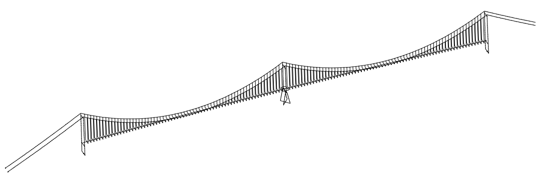

Fig.1 Finite Element Model for Structure Computation

A computation model (fig.1) is built up based on the three tower suspension bridge design for Taizhou project with two main span 1080m.Through analysis we can conclude, the advantage of increasing mid-tower longitudinal rigidity is that the increase may significantly reduce horizontal displacement of mid-tower top, vertical flexibility of main girder and bending moment of main girder midspan. But, the reduction is

https://doi.org/10.2749/222137908796293749

significant only when the mid-tower rigidity is relatively low; if the mid-tower rigidity is already high, it is much less effective to rely on rigidity enhancement to improve the deformation behavior of mid-tower and main girder. The disadvantage is that it also increases both bending moment of mid-tower and the main cable pulling force difference between the sides of tower top.The increase of the latter may lead to gradual deterioration of main cable safety against skid in saddles on the mid-tower top and make it increasingly difficult to anchor the main cables on mid-tower top.

3. Restrictions of Mid-Tower Rigidity Selection

In order to make the design meet the requirements of structural strength, structural deformation, and bridge functions, we must select proper mid-tower rigidity. According to the above analysis, major restrictions related to mid-tower rigidity include:

(1) Vertical rigidity of bridge span is suitable and vertical flexibility of load-bearing span is within certain range.

(2) The problem of main cable skid in saddle is properly solved.

(3) The strength of the mid-tower itself shall be adequately guaranteed.

(4) The longitudinal and transverse stability of the mid-tower shall meet the requirements of relevant codes.

4. Mid-tower Structure Options

In order to obtain a mid-tower type that can be adopted in actual construction, we need to carry out design computations on various mid-tower forms. Except for material and type changes of the mid-tower, other models have similar attributes as the model mentioned in 2.1.Three mid-tower structures are considered in computation. As seen from longitudinal direction, they take the shapes of A, I, and inverted Y. Concrete or steel options are considered in each structure.

5. Conclusions

(1) Along with the increase of longitudinal rigidity of mid-tower, the anti-skid safety coefficient of main cable is decreasing, and so are the max. vertical flexibility of stiffed beam under live load, deflection-span ratio, longitudinal displacement of mid-tower top, max. cross-section compressive stress (general trend) and tensile stress of mid-tower.

(2) Longitudinal rigidity is a key element in structure selection for mid-tower. In a certain structural system, the mid-tower longitudinal rigidity of three-tower suspension bridge shall be kept in certain range. With the selected structural system and required flexibility limit and main cable anti-skid coefficient in the preliminary design of Taizhou Bridge, it is proper to keep the longitudinal rigidity of mid-tower at 23-28MN/m.

(3) According to computation results and on the basis of the structural system adopted in Taizhou Bridge, with the required limits including beam end vertical rotation - 0.02 rad, deflection-span ratio - 1/250, main cable anti-skid friction coefficient at mid-tower - 0.2, and safety coefficient – K>2.0, it is not proper to select A-shape steel, A-shape concrete, I-shape concrete, inverted Y-shape concrete, or inverted Y-shaped steel and concrete structures for the mid-tower.

(4) For the structural system adopted in Taizhou Bridge and with the required limits including beam end vertical rotation - 0.02 rad, deflection-span ratio - 1/250, main cable anti-skid friction coefficient at mid-tower - 0.2, and safety coefficient – K>2.0, it is feasible to select inverted Y-shape steel structure for the mid-tower.