Brief Research on Arch Hinge of Leaning Concrete Filled Steel Tube Arch by Contact Problem under Local Stress

He Wei
Associate Professor
Southwest Jiaotong Univ.
Chengdu, Sichuan, CHINA
harveyhe@swjtu.cn

Liu Yang
CSCEC AECOM Consultants co., LTD
Xian, Shanxi, CHINA
liuyangkaka@126.com

Chen Shasha
Civil Engineer
Southwest Jiaotong Univ.
Chengdu, Sichuan, CHINA
witch99@163.com

Deng Liwen
Civil Engineer
Southwest Jiaotong Univ.
Chengdu, Sichuan, CHINA
lkjx101@163.com

Summary

Leaning concrete-filled steel tube arch is preferable for city bridge because of its wide bridge decking, elegant appearance and reasonable loads transfer. For such bridge, the arch hinge of main arch with special local structure and complex force situation was a critical configuration, it was necessary to analyze the typical stress distribution of the arch hinge. And the analysis was up to contact problem. In this paper, based on the design of Guiyang Road Twelve Nanming Bridge, the common software ANSYS and Hertz contact theory were used to calculate the regional stress of the special arch hinge. The mechanical properties of cylindrical hinge were compared with spherical hinge under different loading condition. The results showed that the leaning concrete-filled steel tube arch should adopt the economic and reasonable cylindrical hinge, and the Hertz's solution is conservative in the analysis of this arch hinge contact problem.

Keywords: leaning arch; concrete filled steel tube; arch hinge; finite element analysis; contact problem; Hertz theory

1. Introduction

Road Twelve Nanming Bridge is located in Guiyang. In the design process, the bridge was required not only to meet the basic design requirements, but also to come up to the standard on landscape evaluation. After careful comparison, the leaning concrete-filled steel tube arch bridge was finally adopted. System transformation that was consolidated at first and then articulated existed in construction of this arch-beam composite structure.

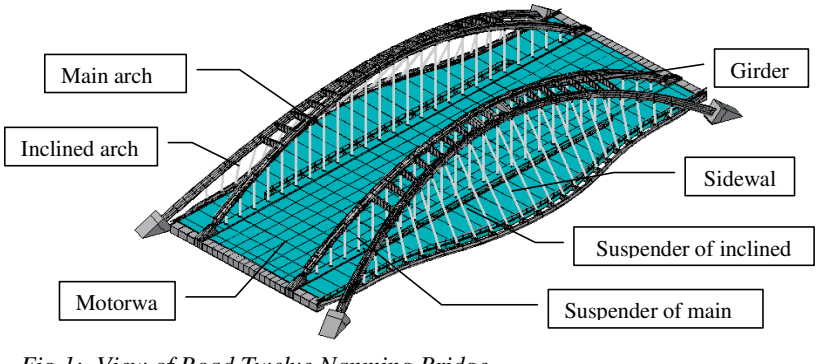

Fig.1: View of Road Twelve Nanming Bridge

2. Analysis of arch hinge

The study of Hertz contact problem was the contact problem of two object under the squeezing loads coming up with local pressure, and the problem of corresponding stress and deformation. Based supposition such as the linear relationship of stress and strain, the result calculated by the Hertz formula cannot meet the requirement of the specification. Then large-scale finite element computation program ANSYS was adopted to discuss the stress condition of arch hinge.

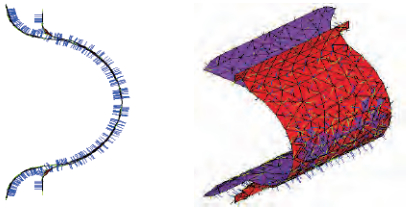

Fig.3: Contact pair on cylindrical surface

Contact problem FEM analysis is highly nonlinear and require significant computer resources to be solved. An efficiently model adopted SOLID95 entity unit and free meshing has been built. For the definition of the material, because of its high elastic material calculation error, elastic-plastic material was chosen to calculate. Contact elements of TARGE170 and CONTA174 were applied on the interfaces between the upper and the lower components in program, as shown in fig.2.

The mechanical properties of cylindrical hinge were calculated under axis force. Furthermore combination of axial force and moment was also considered. There was stress concentration at two sides or one single side of the cylindrical surface, respectively. The maximum equivalent stress reached 274 MPa and 302MPa which was less than the material yield strength. In addition, the equivalent stress for other areas of these points was much less than the material allowable stress and transited relatively smoothly. The contact deformation were comparatively small, and maximum deformation was -2.61×10-4m and -3.06×10-4m, completely met the design requirements. The stress concentration located at the boundary of arch hinge which needed to fillet. Therefore, it was important to ensure that there were sufficiently smooth rounded corners on the sides of arch hinge.

With the load increasing, both the contact stress and deformation of arch hinge showed a trend of increase, but smaller than the results from Hertz's theory. The difference value of stress was from 23% to 38%, while deformation's reached 80%. Traditional Hertz contact theory was an approximate solution under some assumptions which was not suitable enough for the situation of high performance and accuracy. This paper showed that using the Hertz theory to solve the contact problems of this arch hinge was slightly conservative. Further research was recommended.

The analysis of the spherical hinge and cylindrical hinge of different radius showed that the maximum equivalent stress appeared on the contact surface of 0.25m radius, reached 274 MPa and 302MPa, respectively. With the increasing of radius of arch hinge, the contact stress and deformation was decreased. It indicated that the material of ZG310-570 was not able to meet the design requirements because the maximum stress of spherical hinge was higher than the material yield stress. Therefore, higher standards of steel material or larger radius of hinge was needed. And strict quality control of production was required.

3. Conclusion

The designed arch hinge in this bridge could effectively release the in-plane bending moment of the main arch on the location of the arch rib foot, made the force state of bridge structure more reasonable. For elegant appearance and reasonable loads transfer, it was economic and reasonable to adopt the cylindrical hinge of original design in leaning concrete filled steel tube arch bridge. The practical experience gave a reference to other arch-beam composite structure.