Vehicle-induced Vibration of Half-through and Through CFST Arch Bridges

Qing-xiong WU
Associate research fellow
Fuzhou University
Fuzhou, China
wuqingx@fzu.edu.cn

Qing-xiong WU, born 1973, received his Doctor degree of Engineering from Nagasaki University, Japan

Bao-chun CHEN
Professor
Fuzhou University
Fuzhou, China
baochunchen@fzu.edu.cn

Bao-chun Chen, born 1958, received his Doctor degree of Engineering from Kyushu University, Japan

Summary

The road roughness curves and vehicle-induced responses of eight concrete-filled steel tubular (CFST) arch bridges with suspended deck system are obtained by field test. The dynamic analysis considering the interaction between vehicle and bridge are carried out by finite element method. The vehicle-induced vibration analysis of CFST arch bridge is verified by comparing with the measured acceleration responses. The accelerations and velocities in CFST arch rib and suspended deck are then analyzed.

Keywords: Vehicle-induced vibration; concrete-filled steel tubular (CFST) arch bridge; road roughness; velocity response; acceleration response

1. Introduction

Concrete-filled steel tubular (CFST) arch bridges have been developed rapidly in China since 1990 when Wangcang Donghe Bridge was built. Wu-shan Yangtze River Bridge in Chong-qing with a main span of 460m is the longest one up to now. Research on in-plane modal shapes of deck system and arch rib for half-through and though CFST arch bridges were carried out. It was indicated that they were independent, because they are connected by flexible hangers. The vibration of deck and arch rib are not synchronous, commonly the vibration of deck system lag behind that of arch rib. In the real bridge, it is appeared that the deck vibration is rather large when the vehicle passing by. It should be noted that too big vibration in deck system will easily lead to some local fatigue failure of member and has a great influence on riding comfort and safety. In this paper, the vehicle-induced responses of the eight CFST arch bridges were obtained by field test. The finite element models considering the interaction of vehicle and bridge are established. The precision of CFST arch bridge models and vehicle-bridge vibration analysis are verified by comparing with the measured acceleration responses. The comparative analysis of accelerations and velocities in CFST arch rib and suspended deck is carried out using the finite element models.

2. Field test and theoretical analysis on vehicle-induced responses of CFST arch bridge

There are 8 CFST bridges are investigated. 7 of them are in Fujian, China, and 1 in Japan. They are divided into two groups according to their structure: half-through arch with thrust (such as Qunyi, Jiefang, Shitanxi and New Saikai Bridge, located in Nagasaki Prefecture, is the first highway CFST arch bridge in Japan), rigid-frame tied through arch (such as Tongshan, Shanqian and Lanxi Bridge). These 8 bridges are all with suspended deck system.

Taking Shanqian Bridge as an example, the FE model is established. The interation of vehicle and bridge considering road roughness is calculated by direct integration method. The vehicle model with two axials and four DOFs is used. The roughness curve of Shanqian Bridge is measure using

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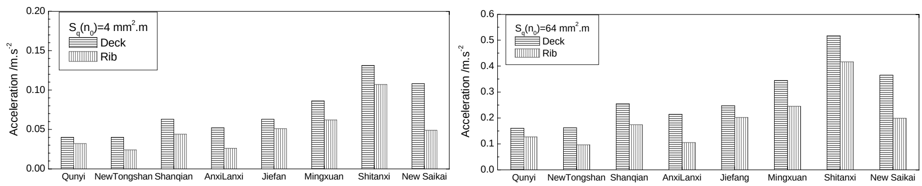
LP300_A. The FEM results are close to the experimental results, so the FE models and vehicle-induced vibration prodecure are validated.

3. Vehicle-induced dynamic characteristics of CFST arch bridges

The single-vehicle model with the speed of 40km/h is applied to evaluate the dynamic performance of those investigated CFST arch bridges. The absolute maximum acceleration and velocity for each CFST arch bridge are shown in Fig.5, in which the dashed line denotes the road roughness coefficient $S_q(n_0)$. The ergonomic evaluation method, which is proposed by Kobori *et al*., is used to evaluate the vibration sensibility of the vehicle-induced vibration on the CFST arch bridges.

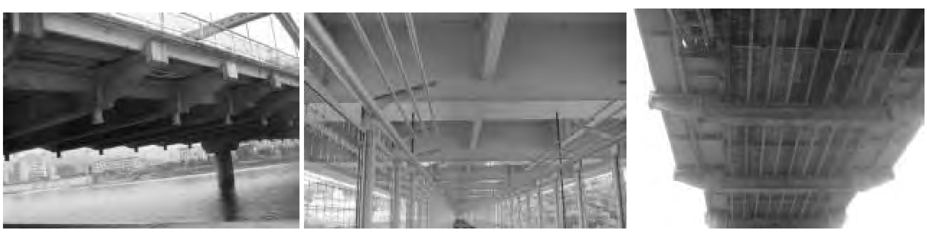
Fig. 1 shows the absolute maximum acceleration of arch rib and deck when the road roughness coefficient $S_q(n_0)$ is 4mm^2.m and 64mm^2.m, respectively. $S_q(n_0)$=4mm^2.m denotes the road roughness in the '*best*' condition according to ISO standard. For rigid-frame tied through CFST arch bridge and the bridge which mainly use longitudinal girder, the dynamic response of arch rib is about 50% smaller than that of deck, while for the CFST arch bridge with no stiffening girder, it is 15% smaller.



Span(m)46 75 80 80 80 90 136 240 Span(m)46 75 80 80 80 90 136 240

(a) $S_q(n_0)$=4 mm^2.m (b) $S_q(n_0)$=64 mm^2.m

Fig.1: Relationship between acceleration and type of deck system



(a) Tongshan Bridge *(c) New Saikai Bridge* *(b) Shitanxi Bridge*

Fig.2: Deck systems of three CFST arch bridges

The deck system of Tongshan Bridge is stiffened by longitudinal girder. It's obvious that the dynamic responses of deck and arch rib are smaller than those of the other two bridges. For New Saikai Bridge the two strong stiffening box girders in the deck system play very important role on dynamic properties, so the dynamic responses of deck and arch rib are obviously smaller than those of the Shantanxi bridge without longitudinal stiffening girders.

4. Conclusions

The calculated acceleration curves and maximum value of CFST arch bridge are close to that of test result, so the CFST arch model and vehicle-induced vibration analysis are verified.

For rigid-frame tied through CFST arch bridge and the bridge which mainly use longitudinal girder, the dynamic response of arch rib is about 50% smaller than that of deck, while for the CFST arch bridge with no stiffening girder, it is 15% smaller.

In order to improve the vehicle-induced responses or keep it well, it is necessary to set the longitudinal stiffening girders in the suspended deck systems of half-through or through CFST arch bridges.