Resonance of a Prestressed Concrete Bridge Under Trains

Chunyu FU
Lecturer
Hohai University
Nanjing, PR China
fuyupiece@163.com

Chunyu Fu, born 1981, got his civil engineering degree from Southwest Jiaotong University, China. Now he works for Hohai University, China. His research areas include the dynamics of cracked structures and health monitoring.

Summary

By considering the vertical-horizontal interations, this paper investigates the effect of the prestress on the vibration of the bridge subjected to high-speed trains. Lagrange's equations are adopted to obtain the finite element equations of motion for the train-bridge coupling system, where the horizontal-vertical interaction is represented by an equivalent stiffness, and the effect of high-order displacements is expressed by an equivalent load. The proposed method is validated by a simply supported bridge, and the results show that due to the effects of horizontal-vertical interactions, the horizontal prestress forces can enlarge the vertical displacements of the bridge at resonance, while the vertical vehicular loads can cause the bridge vibration in horizontal direction.

Key words: train-bridge coupling system; prestressed concrete bridge; vertical-horizontal interaction; finite element method; resonance; equivalent load.

1. Introduction

With the fast growing demand of high-speed railways, there are more and more prestressed concrete bridges with bond cables, where a large horizontal prestress is often designed to offset the static displacement caused by dead loads. However, the effect of the prestress on the vibrational displacement tends to be neglected [1]. In fact, the prestress may change during the vibration [2], and in turn influence the vibrational displacements of the bridge. Therefore, it is necessary to investigate the effect of the prestress on the vibration of the bridge subjected to high-speed trains.

Many methods have been developed to analyze the vibration of the train-bridge coupling system, especially the resonant vibration which is more likely to occur due to the coincidence between the loading frequencies of high-speed trains and the natural frequencies of the bridges. Fryba [3]studied in theory the dynamic response of a beam under moving loads and proposed the corresponding resonance formula. Li and Su [4] researched the resonant vibration for a simply supported girder under high-speed trains, using a vehicle model with a rigid body and four wheel-axle sets. Yang et al. [5]analyzed the key parameters that governed the resonance of the simply supported beam, and proposed the optimal design criteria that were effective for suppressing the resonance. Xia et al. [1] analyzed the resonance mechanism and conditions caused by moving load series, the loading rate, and the swing forces.

However, to the best of the author's knowledge, relatively little information is available on the

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