

Using elastic bridge bearings to reduce train-induced ground vibrations: An experimental and numerical study

Xiaozhen Li^{a,b}, Zhijun Zhang^{a,b}, Xun Zhang^{a,b,*}

^a Department of Bridge Engineering, School of Civil Engineering, Southwest Jiaotong University, Chengdu 610031, China

^b MOE Key Laboratory of High-Speed Railway Engineering, Southwest Jiaotong University, China

ARTICLE INFO

Article history:

Received 20 October 2015

Received in revised form

22 January 2016

Accepted 14 March 2016

Keywords:

High-speed rail

Elevated bridge

Ground vibration

Elastic bearing

Numerical simulation

Field experiment

ABSTRACT

In order to investigate the influences of elastic bearings on ground vibrations induced by trains traversing a bridge, a numerical model was established based on the combination of train/track/bridge and pier/pile/soil subsystems. The elastic bearings in the train/track/bridge subsystem were simulated by a spring-dashpot element. The two subsystems were linked by the bearing reaction forces, and the whole model was calculated in the time domain. The numerically computed ground vibrations were compared with measured ones to validate the model. On this basis, the influences of elastic bearings on train, bridge and ground responses were discussed. Results show that the dynamic responses of the train are hardly affected, while the dynamic responses at the pier top and on the ground are clearly attenuated in the frequency band above 40 Hz. Some increments in the frequency range 8–30 Hz can be observed around the eigenfrequency of the main girder-elastic bearing system. The laws of bearing stiffness influences on ground vibrations were similar for different stiffnesses of the elastic bearings. Within a distance of 15 m from the bridge, elastic bearings with stiffnesses of 2400, 2000 and 1600 MN/m can reduce ground vibrations. However, at locations more than 22.5 m from the bridge, ground vibrations may be close to or even a little larger than those of the rigid bearing case. When the elastic bearing has a stiffness of 1200 MN/m, ground vibrations are clearly decreased at all locations.

© 2016 Published by Elsevier Ltd.

1. Introduction

China has the world's longest high-speed rail (HSR) lines, with over 16,000 km of track in service as of December 2014, which is more than the rest of the world's HSR tracks combined. The emergence and increase of HSR lines has provided a rapid and convenient traffic medium, but, at the same time, has generated environmental problems. Ground vibrations induced by the passage of high-speed trains can reach levels that cause annoyance to humans and the interruption of sensitive instrumentation and processes. These seem to have been tolerated in the past, but are now increasingly being considered a nuisance. Therefore, effective countermeasures are being urgently sought.

Some measures have already been investigated, such as open or in-filled trenches [1,2], barriers of piles [3,4] and wave impedance blocks [5,6]. Each of these measures is expensive. Moreover, some traditional measures, such as barriers, have often turned out to be unsuccessful in many cases [6]. Therefore, it is worthwhile

developing a new method. Elastic bearings, with some flexibility in the vertical direction, have been used on HSR bridges in Taiwan to reduce the environmental vibrations induced by trains crossing them [7]. For the same reason, elastic bearings have also been used on the Yichang Yangtze River bridge of the Yichang–Wanzhou railway line and on the Minjiang River bridge of the Fuzhou–Xiamen railway line, in China [8]. Therefore, as described above, elastic bearings have been applied in practice to reduce ground vibrations, even though relevant theoretical research is very limited. Kawatani et al. analyzed the dynamic responses of a highway bridge with elastic bearings by combining theoretical analysis with experiments [9–11]. The elastic bearing performances and their influences on the bridge dynamic responses were evaluated, and the influences of elastic bearings on train-running characteristics and bridge dynamic responses were then explored [12]. Obviously, this theoretical research was not concerned with ground vibrations. Therefore, it remains necessary to clarify the mitigating effects of elastic bearings on ground vibrations induced by passing trains on bridges.

An accurate prediction model of ground vibration is required so that the effects of elastic bearings can be discussed appropriately. With the development of computer simulation techniques, the finite element (FE) method and/or the boundary element (BE)

* Corresponding author at: Department of Bridge Engineering, School of Civil Engineering, Southwest Jiaotong University, Chengdu 610031, China. Tel./fax: +86 28 87603323.

E-mail address: zhxunxun@swjtu.edu.cn (X. Zhang).

method can be applied to the calculation of traffic-induced ground vibrations. Ju [13] used a three-dimensional (3D) FE model incorporating an absorbing boundary condition to simulate soil vibration due to a high-speed train moving across a bridge. Celebi and Schmid [14] used a thin layer method and BE model to analyze the 3D dynamic response of the free field adjacent to the railway line. Yang and Hung [15,16] proposed a 2.5D finite/infinite element procedure to deal with the soil vibrations induced by moving loads, which divided the half-space into a near field and a semi-infinite far field. In addition, numerical models using both FE and BE methods are under development for wave propagation problems in solids, with an emphasis on the dynamic soil-structure interaction due to the passage of a train [17].

Existing studies have mainly employed wave propagation in the soil, and have drawn some meaningful conclusions. However, the coupled vibration between the train and bridge has usually been considered with a simplified model, and the effects of elastic bearings on ground vibration have not been studied. In order to address these issues, this paper presents a ground vibration prediction method by combining a train/track/bridge coupling vibration model with a pier/pile/soil coupling vibration model. An *in situ* measurement was conducted near a bridge site, and the proposed method was validated by comparing the computed ground vibrations with the measured ones. Finally, the influences of elastic bearings on ground vibrations are investigated.

2. Methods and models

2.1. Numerical simulation procedure

The analysis of ground vibration due to elevated rail transit involves a complex system including the train, track, bridge and soil. It is very difficult to analyze this complex problem, so the system is divided into two subsystems, namely a train/track/bridge subsystem and a pier/pile/soil subsystem, as shown in Fig. 1. This shows that the reaction forces of the bridge bearings are used to link the two subsystems. The train/track/bridge coupling vibration

analysis is conducted first to obtain the reaction forces of the bridge bearings, and these excitations are applied to the pier/pile/soil subsystem. A 3D FE model incorporating the 3D viscous-spring artificial boundary condition is introduced into the pier/pile/soil subsystem.

2.2. Train/track/bridge subsystem

2.2.1. Train model

The train model is established based on multi-body dynamics. A train is composed of independent vehicles, and each four-axle vehicle consists of seven rigid bodies, namely one car body, two bogies and four wheel-sets (see top of Fig. 1). With the exception of longitudinal vibration, five degrees of freedoms (DOFs) are considered for each rigid body: lateral, vertical, rolling, yawing and pitching movements. Therefore, each vehicle has 35 DOFs in total. In addition, the model thoroughly considers the linear or non-linear stiffness and damping properties of the primary and the secondary suspensions in three directions— x , y and z —which are modeled as spring-dashpot elements.

2.2.2. Track model

In China, ballastless track structures are widely used on high-speed railway bridges. Among them, the slab track is the most common type. The Tianjin–Qinhuangdao railway, like the majority of high-speed rail systems in China, uses the slab track (see Fig. 2).

Fig. 2(a) shows a schematic diagram of the slab track. It consists of 60 kg/m rail, fastener system, track slab, cement-asphalt (CA) mortar, bearing layer and sliding layer. Fig. 2(b) and (c) shows the mechanical model of the slab track. The slab track is modeled as a discretely supported two-layer system considering the DOFs of the rail and the track slab, since vibration of the track system is mainly represented by the rail and the track slab. The rail is modeled as a continuous Euler–Bernoulli beam supported at discrete points by springs and dashpots. Vertical, lateral and torsional vibrations of the rail are considered. The track slab is modeled in the vertical direction, as a rectangular plate of uniform thickness on an elastic

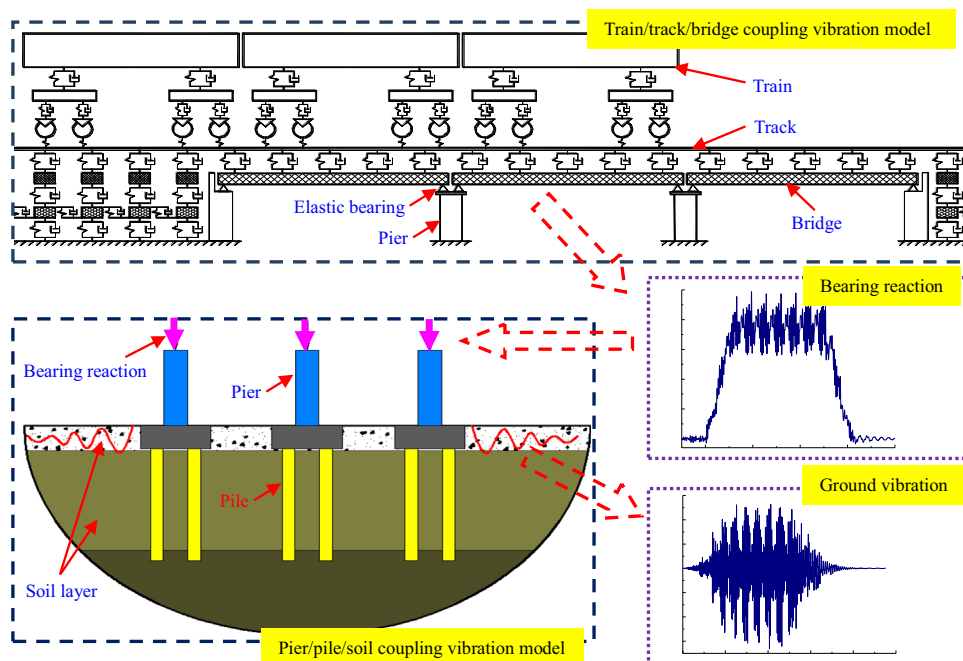


Fig. 1. Schematic diagram of the numerical simulation procedure.

Download English Version:

<https://daneshyari.com/en/article/6771360>

Download Persian Version:

<https://daneshyari.com/article/6771360>

[Daneshyari.com](https://daneshyari.com)