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Dominant frequencies of train-induced vibrations in a seasonally frozen region

Zi-yu Wang [a,*], Xian-zhang Ling [a,b], Zhan-yuan Zhu [c], Feng Zhang [d]

[a] School of Civil Engineering, Harbin Institute of Technology, Harbin 150090, China
[b] State Key Laboratory of Frozen Soils Engineering, Chinese Academy of Science, Gansu, Lanzhou 730000, China
[c] Urban and Rural Construction College, Sichuan Agricultural University, Sichuan, Dujiangyan 611830, China
[d] School of Transportation Science and Engineering, Harbin Institute of Technology, Harbin 150090, China

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ABSTRACT

To investigate the acceleration response in frequency domain of subgrade vibrations induced by moving vehicles in a seasonally frozen region, three field experiments were carried out in the Daqing area of China in spring, summer and winter, respectively. The results show that: (1) there are several frequency bands in an acceleration frequency spectrum, within each frequency band there is a peak frequency which can be computed using the simple equations obtained in this paper; (2) acceleration response in frequency domain is influenced by train types, the train formation, travel speed and train load together; and (3) the main frequency in vertical and longitudinal directions is the largest in the freezing period, followed by unfrozen period and minimum in thawing period.

1. Introduction

With the rapid progress of computer technologies, models were based on the finite-element method, discrete element method, the boundary element method, or coupled together. Some studies were proposed to investigate the ground vibrations through establishing a track system-saturated model (Cai et al., 2008; Cai et al., 2010; Cao et al., 2011). It was found that when the train speed approaches the Rayleigh wave speed of the ground, the single-phase elastic soil model would underestimate the ground vibrations significantly, and the poroelastic soil model was essential for the prediction of train-induced ground vibrations. Wolfert et al. found that the variations of train speed may have some effects on the train-induced ground vibrations (Wolfert et al., 1997; Cao and Bostrom, 2013). In the present study, an analytical model is proposed (Lefeuve-Mesgouez and Mesgouez, 2008; Lefeuve-Mesgouez and Mesgouez, 2012; Coulier et al., 2013; El Kacimi et al., 2013; Huanga and Chrismer, 2013) with discrete element or finite element coupled train-track model for the numerical simulation of the train-induced vibration response, respectively. Lombaert proposes that the quasi-static excitation is related to the static component of the train's axle loads (Lombaert and Degrande, 2009). Considering the coupling effects between the soil skeleton and the fluid, the saturated poroelastic soil model was applied in some investigations of the ground vibrations induced by moving-load (Xu et al., 2007). Moreover, field experiments provide the essential data for the further comparison analysis and verification theoretical methodologies and numerical simulation models. Some researchers have performed field experiments to investigate the ground vibration induced by the passing trains (De Nie, 1948; Dawn and Stanworth, 1979; Mao, 1987; Pan and Xie, 1990; Sunaga et al., 1990a; Sunaga et al., 1990b; Takemiya, 2005; Ling et al., 2010; Kouroussis et al., 2011). Furthermore, Shen-Haw Ju and H. Xia et al. investigated dynamic characteristics by moving vehicles through field experiments and theoretical solutions together (Xia et al., 2006; Ju et al., 2009a). Xian-zhang Ling et al. investigated the vibration characteristics and attenuation of the embankment in a seasonally frozen region (Ling et al., 2009). Yong Lu et al. mention dominant frequency arising from the repeated loads (hence are related to the time interval between two consecutive carriage loads) (Ju et al., 2009b; Lu et al., 2012). Ling Xianzhang et al. analyzed frequency domain characteristics of frozen subgrade vibrations induced by moving vehicles through field experiments, and got the relationship between running speed and the first main frequency(Ling et al., 2010; Xianzhang et al., 2010). At the same time, they found that running speed has great influence on frozen subgrade than unfrozen (Xianzhang et al., 2010). Xia He et al. have a detailed analysis of the vibration frequency attenuation characteristics of subgrade with 1/3 octave spectra (He et al., 2010).

However, until recently, there wasn't research on acceleration peek frequencies of spectrums through monitoring acceleration in different

* Corresponding author at: School of Civil Engineering, Harbin Institute of Technology, Harbin 150090, China.
E-mail address: iamwziyu@163.com (Z. Wang).

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Fig. 1. Overview of the experimental site.

seasons to investigate the vibration response in seasonally frozen regions. And the influence factors of vibration characteristics such as different seasons, vibration directions, train travel speed, train type and train formation are described via acceleration frequency spectrums for the first time. In this paper, to investigate the dynamic characteristics of ground vibrations induced by moving vehicles in a seasonally frozen region, three field experiments were carried out in Daqing area of China in spring, summer and winter, respectively.

2. Monitoring scheme

2.1. Information of the field experiments

The field monitoring site is located at section K124 + 118 (i.e., 124 km and 118 m from Harbin) of the Harbin–Daqing Railway Line, which is situated in Daqing City, Heilongjiang Province, in the northeast China. The pictures of the monitoring site are shown in Fig. 1. In Daqing city, the freezing period lasts from October to mid-March of the second year, and the thawing period lasts from mid-March to May, and the other four months are considered to be the unfrozen period. The highest temperature reaches 37 °C in summer, and the lowest temperature reaches minus 35 °C in winter. Meanwhile, the maximum frozen boundary and groundwater level are about 2 m below the ground surface (Ling et al., 2009).

In this paper, accelerometers of the type 891-2 with available frequency ranges of 0.5 Hz to 100 Hz were used to obtain the measurements in the field experiments. The INV306 signal acquisition system and the DASP signal analyzing system were used to store the measurements; a velocimeter was used to measure the travel speed of the passing train, and detailed vehicle information was acquired from the monitoring station of the train.

At the experimental site, four measuring points were arranged on the cross-section of the railway track as follows: point C1 was arranged at the shoulder of the road; point C2 was at surface layer of embankment; point C3 was at bottom the layer of embankment and point C4 was at the foundation. As shown in Fig. 2 the lateral distances to the railway track, four measuring points were 2.5 m, 4.5 m, 6.8 m and 8.9 m, respectively. At each measuring point, three accelerometers

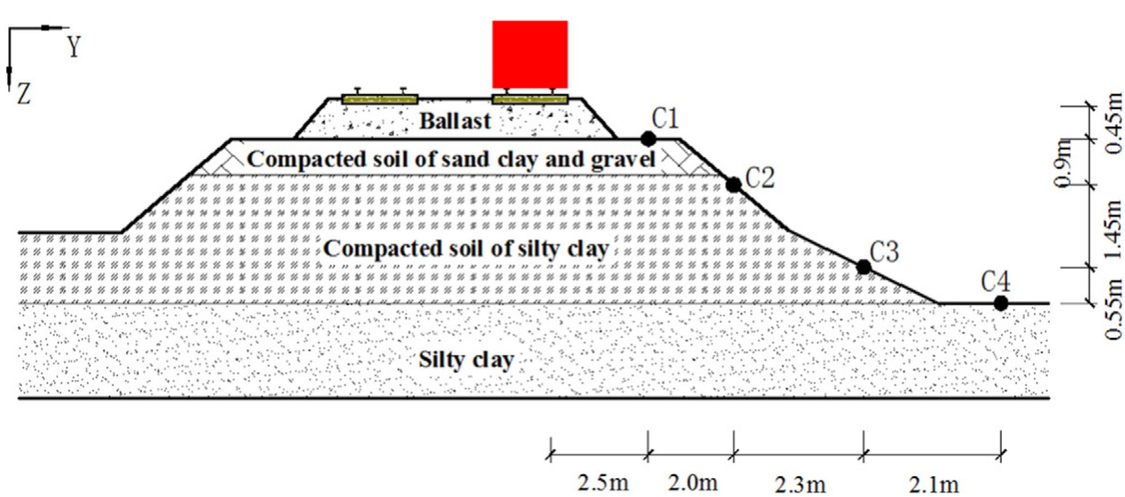

Fig. 2. Geometry of monitoring section and layout map of sensors in Daqing–Harbin railway, China.