The 2019 World Congress on
Advances in Structural Engineering and Mechanics (ASEM19)
Jeju Island, Korea, September 17 - 21, 2019

Extraction of bridge information based on the double-pass double-vehicle technique

Y. Zhan[1], F.T.K. Au[1] and D. Yang[*2]

[1]*Department of Civil Engineering, The University of Hong Kong, Pokfulam, Hong Kong, China*
[2]*Department of Civil Engineering, Hefei University of Technology, Hefei, China*

(Received keep as blank , Revised keep as blank , Accepted keep as blank)

Abstract. To identify the bridge information from the response of test vehicles passing on it (also known as the indirect approach) has aroused the interest of many researchers thanks to its economy, easy implementation and less disruption to traffic. The surface roughness of bridge remains an obstacle for such method as it contaminates the vehicle response severely and thereby renders many vehicle-response-based bridge identification methods ineffective. This paper aims to eliminate such effect with the responses of two different test vehicles. The proposed method can estimate the surface profile of a bridge based on the acceleration data of the vehicles running on the bridge successively, and obtain the normalized contact point response, which proves to be relatively immune to surface roughness. The frequencies and mode shapes of bridge can be further extracted from the normalized contact point acceleration with spectral analysis and Hilbert transform. The effectiveness of the proposed method is verified numerically with a three-span continuous bridge. The influence of measurement noise is also examined.

Keywords: indirect approach, surface roughness, normalized contact point acceleration, mode shape identification.

1. Introduction

The phenomenon of vehicle-bridge coupling vibration allows the response of a vehicle passing on a bridge to contain the bridge information. To extract useful bridge information from vehicle response is known as the indirect approach. Such methods own the advantages of convenience and economy due to less hindrance to traffic and fewer sensors required on the test vehicle as compared to the number of sensors required on a bridge in traditional structural health monitoring system. Many meaningful studies have been carried out and methods to identify bridge frequency (Yang *et al.* 2004; Lin and Yang 2005; Yang and Chang 2009), damping (González *et al.* 2012; Keenahan *et al.* 2014; Yang *et al.* 2019) and mode shape (Oshima *et al.* 2014; Malekjafarian and Obrien 2017), to locate damage (Bu *et al.* 2006; Zhang *et al.* 2012; He *et al.* 2014; Li and Au 2014; O'Brien and Keenahan 2015) and to access bridge condition (Kim *et al.* 2014) have been proposed. Two reviews about the works in this field are available (Malekjafarian *et al.* 2015; Yang and Yang 2017).

The surface roughness severely contaminates the vehicle response and masks the components

*Corresponding author, Associate Professor, E-mail: yangdong@hfut.edu.cn

Note: Copied from the manuscript submitted to
"Smart Structures and Systems, An International Journal" for the purpose of presentation at ASEM19.

that are related to bridge vibration. Therefore, it is a major impediment for the indirect approach to go from theory to application. The adverse effect of surface roughness has been pointed out and discussed by researchers, such as Elhattab *et al.* (2016), Qi and Au (2016). Most studies assume bridge to have smooth surface or consider it but in an impractically small magnitude. Many efforts have been made to overcome such an obstacle. Yang *et al.* (2012) employed two connected vehicles to mitigate the blurring effect of road surface roughness in bridge frequency identification. Oshima *et al.* (2014) developed a monitoring system composed of more than four monitoring vehicles and two heavy trucks to estimate bridge mode shapes and access bridge condition. O'Brien *et al.* (2014) composed an algorithm to derive dynamic vehicle-bridge interaction forces from the vehicle response, based on which the global bending stiffness and roughness profile of the bridge can be identified. However, the multi-vehicle system is expected to encounter difficulties in real applications as the assumptions in simulation can hardly be met in reality for such a complicate system.

This paper addresses this problem by obtaining an estimation of surface profile from the acceleration of two different test vehicles traverse the bridge successively. The normalized contact point acceleration (NCPA) is then obtained, which is relatively immune to the influence of surface roughness. The bridge information such as frequencies and mode shapes can be identified from NCPA accordingly.

There exist several methods to detect surface profile. Nowadays the highway authorities usually resort to the use of road surface profiler, which is essentially a vehicle with laser sensors to record the distance between the road surface and the receiver, and accelerometers to record and compensate the body movement. It provides accurate surface profile, but the shortcomings are also obvious: expensive to purchase, time-consuming, strict operation condition requirements and high maintenance costs. In addition, the identified surface profile is quite different from what the vehicle experiences due to the stiffness of tyre and width of the wheel (Captain *et al.* 1979; Chang *et al.* 2011; Camara *et al.* 2014). Fig. 1 shows their difference due to width of the wheel. To eliminate the influence of surface roughness on vehicle response, the experienced, rather than the exact surface profile is needed. In this paper the experienced surface roughness is identified based on the response of the vehicle entirely.

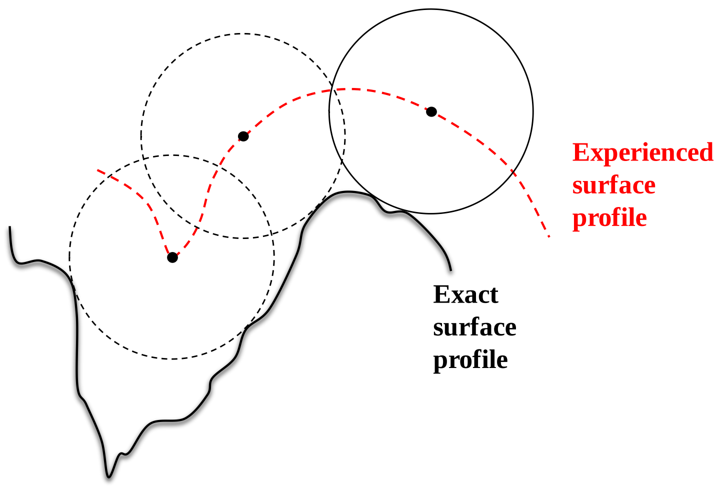

Fig. 1 Difference of exact and experienced surface profiles due to the width of wheel