Non-Contact Seismic Lamb Wave Measurement of Pavement Structure using Laser Array

Summary

We propose a novel non-contact seismic Lamb wave measurement using laser array to estimate the elastic properties and thicknesses of asphalt concrete (AC) pavement systems. Compared to the conventional techniques such as Falling Weigh Deflectometer (FWD), our method provides higher resolution, more stability in back-calculation, and in particular, **faster data acquisition**. Using high frequency Lamb waves, we can distinguish some fine structures in pavements such as delamination. In addition, our fast data acquisition technique is mobile. In other words, unlike FWD, we **do not have to stop** the acquisition vehicle and block traffic for data collection. Hence, our approach will yield continuous measurement of pavement elastic properties.

Introduction

The Lamb wave is a high frequency seismic wave that propagates in solid plates (Ryden et al, 2003; 2004). The Lamb wave exhibits dispersion property that is the dependency of the velocity on frequency. Dispersion is quantified by the phase or group velocities. The phase velocity is the velocity of each frequency component whereas the group velocity is the velocity of a pocket of frequencies (Askari and Ferguson, 2012). For a given a pavement model, the phase and group velocities of the Lamb wave depend on the S-and P-wave velocities, thicknesses and densities of AC, base, and subgrade (Ryden et al, 2003, 2004). Therefore, providing that we measure either phase or group velocities of the Lamb wave, we can determine the thickness, stiffness, Poisson ratio, and Young modulus of AC pavements.

The advantages of our proposed technique to characterize the elastic properties of pavement over the conventional methods such as Falling Weigh Deflectometer (FWD) are

1) Compared to the deflection measurements used in FWD, the Lamb wave has higher frequencies (Ryden et al, 2003, 2004) that yields high-resolution characterization of pavements. ***Some fine features such as delamination can be distinguished using the dispersion curve analysis of the Lamb wave.***
2) ***Unlike FWD, the inversion (process similar to back-calculation in FWD) of the Lamb wave has less uncertainty*** because it uses a wider range of frequencies. In addition, the back-calculation of asphalt concrete (AC) is less affected by the mechanical properties of deeper embedded layers (Aouad et al., 1993; Bjurström et al., 2016a).
3) To obtain the phase or group velocities of the Lamb wave, full waveforms of the Lamb wave, recorded at different geophones, are used via a stacking procedure (Ryden and Park, 2006). Therefore, ***the bac-calculation of Lamb is more resistant to noise***.
4) ***We propose a novel acquisition technique via Laser Array (LA) that significantly expedites acquisition compared to FWD. Our fast data acquisition technique will yield continuous measurement of pavement elastic properties.***

Lamb Wave Data Acquisition using Layer Array

The Lamb wave can be acquired using a conventional seismic refraction profile. However, a fast data acquisition requires the refraction profile not to touch the highway. Bjurström et al. (2016b) suggest that the receivers be microphones that detect the weak acoustic wave coupled to the atmosphere from the seismic Lamb wave motion. The Bjurström et al. approach is highly vulnerable to asphalt roughness that causes systematic errors in back-calculation. In addition, due to the poor energy of the acoustic wave, the data acquisition is not possible in windy environments. Another drawback of the Bjurström et al. method is its limited speed (almost walking speed).

We propose a novel Lamb wave measurement by using lasers as the non-contact seismic sensor. Using laser as a seismic receiver is not new. Berni (1994) used laser-based systems in two experimental studies in 1994. More recently, laser has been used in Rolling Weight Deflectometer (RWD) to measure pavement deflection (Elbagalati et al., 2017). Our data acquisition resembles RWD, however it will be calibrated to acquire high frequency Lamb wave. Figure 1schematicaaly shows our proposed use of a trolley of lasers plus a seismic source as the mobile seismic recording system.

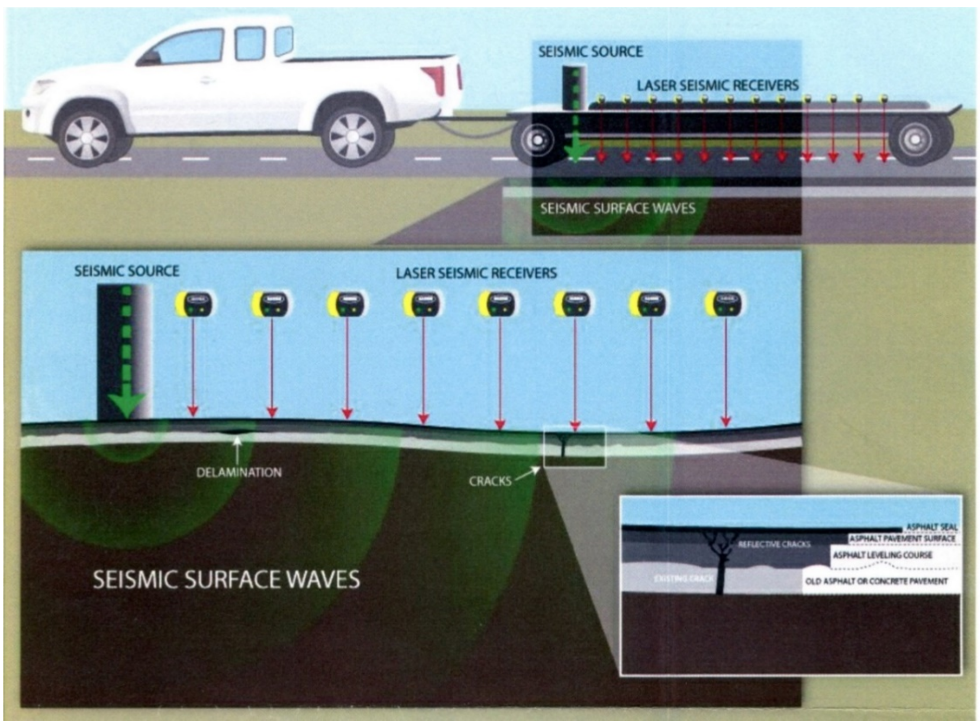

Figure 1 Cartoon of the mobile seismic recording system using lasers as seismic receivers. Also shown are the seismic surface waves and the perturbations in the asphalt layers and in the base that we wish to detect with those waves.

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