Delineation of S-wave velocity structure of pavements and embankments by means of high-frequency surface wave measurements

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Special attention should be paid not only to the surface pavement but also to such artificial layers as embankments and fills when applying near surface geophysics (NSG) to the subsurface up to 30 m depth. Conventional geophysical studies of the Earth’ s interior have ignored or treated the near surface as a nuisance or a noise source. Conversely, our social activities have fundamentally been being operated in the near surfaces. Since NSG should play an important role for assessing the present state and future deterioration potential of infrastructures mainly founded on and in the near surfaces, through delineating their heterogeneous structures, and through characterizing their physical properties such as bearing strength and seismic resistance. On the other hand, surface pavement layer, which is a quite common substance in urban areas, has made it difficult to apply seismic refraction surveying because of the velocity overturning, and the existence of a number of buried metallic pipes at shallow depths too for applying EM measurements. In contrast, seismic reflection and surface wave method have the capability of delineating velocity structures in the near surfaces even through the surface pavements. Actually we have conducted a number of near surface surveys in urban areas utilizing SH-wave type and surface wave type Land Streamers. Target depths of the surveys were from 100 m to 5m. We could expand the opportunity of applying NSG to pavement structure surveying when we make the target depth shallower than 1.5 m. One of the most useful tools for ultra-shallow surveys is GPR (Ground Penetrating Radar), and actually it has been widely used for detecting voids beneath the pavement. It can locate voids, however, but does not provide information on physical properties of pavements indispensable for road maintenance. In contrast, surface wave method can yield S-wave velocity structure of the subsurface. Our recent studies have revealed that high-frequency dispersion curves up to 500 Hz were obtained by means of the Land Streamer, developed by the first author, which mounted a conventional 4.5 Hz geophone on a metallic baseplate coupled non-adhesively with pavement surface. In addition, we demonstrated that an accelerometer array tool had wide frequency range up to 4 kHz, but adhesion of accelerometer sensors, it forced time-consuming and dangerous works on roadways, were critical for obtaining high quality records. Dispersion curves up to 4 kHz enabled us to reconstruct S-wave velocity structures at depths of 15 cm to 2 m or more. It was required to obtain dispersion curves up to 8 kHz for the estimation of S-wave velocity and thickness of the uppermost asphalt concrete layer, which was the key for assessing traveling performance of roadway. Then we newly developed a non-contact surface wave measurement tool using an air-coupled microphone array for the structural investigation of pavements. The tool comprises two microphone arrays, suspended 2 cm above the pavement surface. The microphone array observes leaky surface waves under air-coupled condition. Field measurements demonstrated that the tool could measure surface waves which showed clear dispersion in the frequency range from 40 to 8,000 Hz. S-wave velocity structure of the pavement up to 1 m was successfully reconstructed from the higher modes or Lamb mode of surface waves. To certify whether the dispersion curves measured by the tool were valid, we conducted check drilling and forward modelling based on the drilling data. Observed dispersion curves were well matched with those calculated from the actual pavement structure.

Keywords: surface wave, leaky surface wave, high frequency, higher mode, artificial layer