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Consideration of Cavity Detection Applicability of SASW Technique Through the Model Test

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Abstract This paper presents a detection technique for determination of the cavity existence under slab track of railway. The detection technique is based on the Spectral Analysis of Surface Wave (SASW) test. The SASW test is a non-destructive seismic method which uses Rayleigh-type waves to measure in situ shear wave velocity (Vs) of soil. It is found form field model tests that underground obstacles or buried objects and soil heterogeneity significantly affect surface (Rayleigh) wave dispersion. Cavities and obstacles looser than the surrounding soil cause a decrease in the shear wave velocity. The theoretical background and field implementation procedures of using SASW for detecting cavity below the slab track are explained.

***Keywords*:** SASW, Cavity, Ground, Railway slab track

1. INTRODUCTION

The Spectral Analysis of Surface Waves (SASW) method is widely used to determine the dynamic shear modulus and the material damping ratio of soils. This method uses the dispersive characteristics of surface waves to determine the variation of the shear wave velocity of layered systems with depth. Once the shear wave velocity profiles are determined, shear and Young's modulus of the materials can be estimated through the use of elastic wave theory equations. In this study, use of the SASW for detecting cavity in the ground is introduced and tested in the field for verifying purpose. Detail procedure for using SASW to detect a cavity in the ground is developed and explained thoroughly.

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2. THEORY

2.1 SASW Testing Method

2.1.1Theory

Shear and compression waves are the two main modes of propagation of acoustic elastic energy in solids. With shear waves, also called transverse waves, the particles of the medium oscillate at a right angle to the direction of propagation. In compression waves the oscillations occur in the longitudinal direction or the direction of wave propagation. The wave speeds of these different kinds of waves are governed by two different types of modulus. Shear waves of varying wavelengths penetrate to different depths and travel at the velocity of the mediums into which they are travelling. For example, longer wavelengths penetrate deeper and their velocity is affected by the material properties at greater depth (Fig.1).

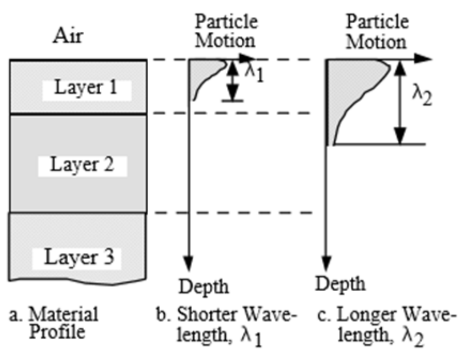


Fig. 1 Wavelength penetration in SASW testing

The Phase Velocity (V_{ph}) and Phase Wavelength (λ_{ph}) are defined below, where f represents frequency in H_z, and β is the phase difference between two sensors in degree obtained by cross power spectrum of signals [1].

$$V_{ph} = \frac{360 * f}{\beta} \quad (1)$$

$$\lambda_{ph} = \frac{V_{ph}}{f} \quad (2)$$

After a dispersion curve is calculated from the field data, according to approach developed by Kausel and Roesset [2], the shear wave velocity profile is determined as follows:

$$V_s = 0.92 V_{ph} \quad (3)$$

$$\text{Depth} \approx \frac{\lambda_{ph}}{2} \tag{4}$$

2.1.2 System configuration

A schematic of SASW testing configuration is presented in Fig. 2. An impact source is used to generate surface waves which are recorded by two sensors, DAQ devices and computer.

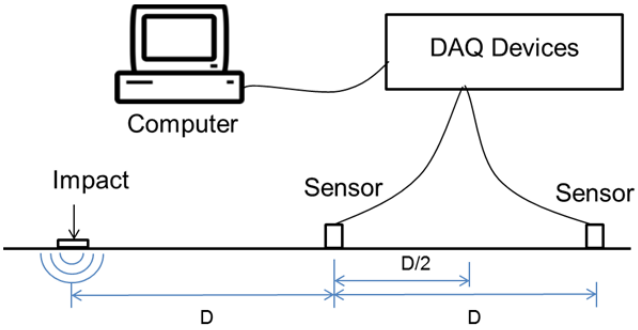


Fig. 2 SASW set up

The suggested array distance D for an experimental composition of SASW test and/or sensor spacing which is equivalent to the range from source to near sensor is described by Heisey et al [3] as follows and adapted in this study.

$$\frac{\lambda_{ph}}{3} < D < 2\lambda_{ph} \tag{5}$$

2.2 Test results

2.2.1 Overview of test site

A test site is selected for checking effectiveness of application of SASW to detect cavity in the ground. The test site is constructed after excavation of existing ground that is refilled with the excavated soils and re-compacted. The site is located in Yong-In, South Korea. The test site is constructed to simulate a model that is representing a soil ground with cavities below railway track. The width and the length of the model site is 5m wide and 25m long respectively. Depth of the model site is 3.2 m approximately including an asphalt layer on the top surface of the ground (Fig. 3).

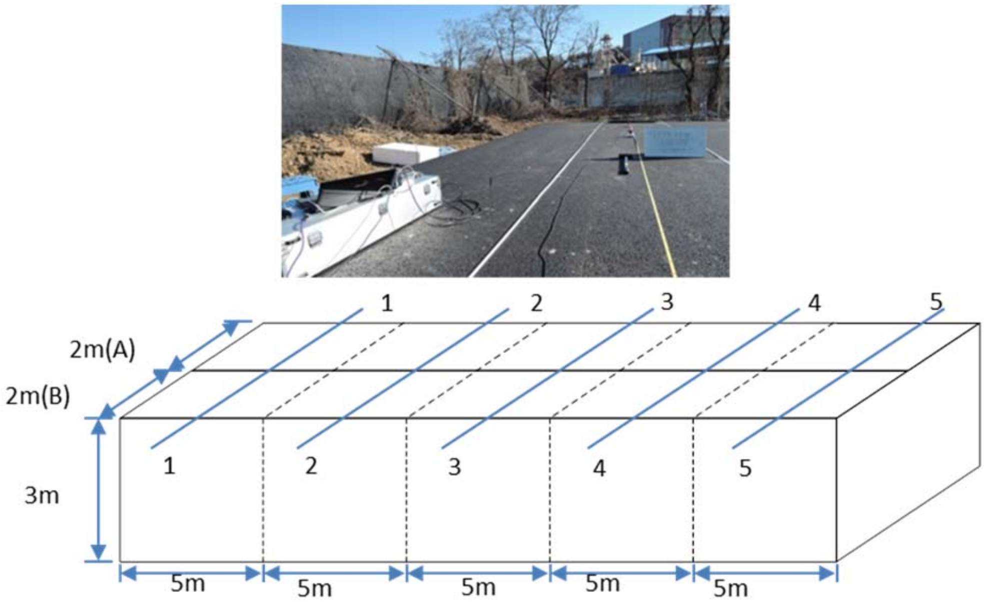
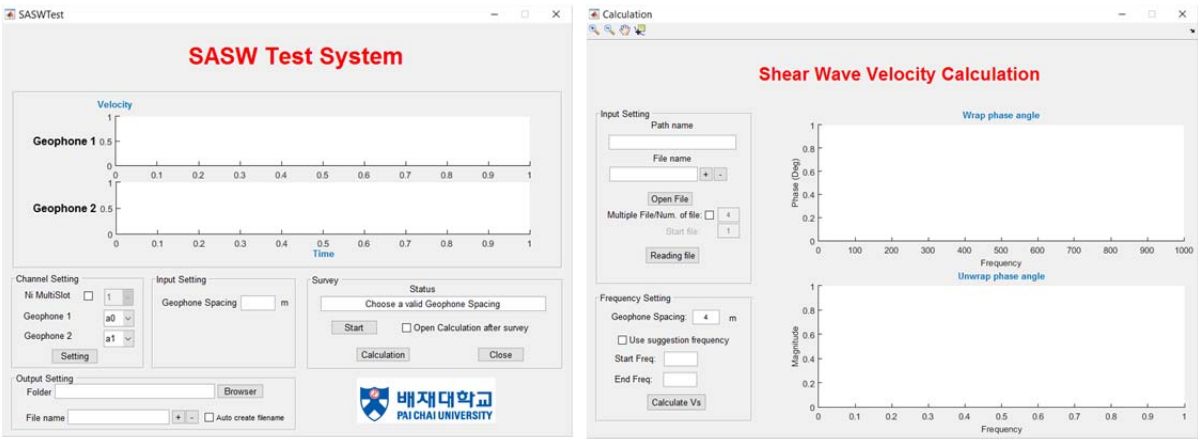


Fig.3 Test site with cavities

At some positions, in order to simulate the cavity, wrapped sponge bundles are included in the model test site. A large size concrete pipe (D=500mm), and 2 stone blocks (700x500x350mm) are also included in the site to simulate unfavorable circumstances.

2.2.2 Analysis program for SASW application

An analysis program called "SASW TEST SYSTEM" in use for SASW application to the model site is developed by Railway infrastructure Laboratory of Paichai University. It contains two separate modules: (1)"Shear wave propagation survey" and (2)"Shear wave velocity calculation".

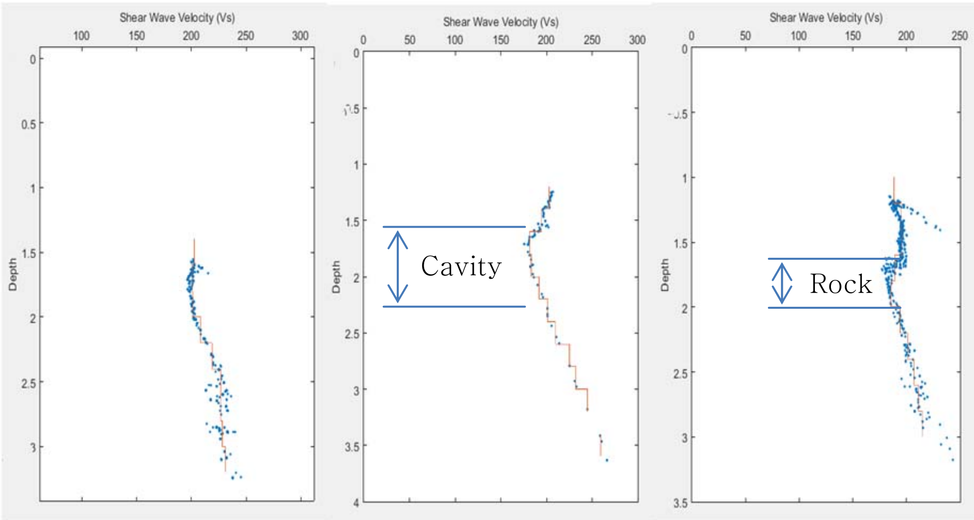


(a) SASW test system module (b) Shear wave velocity calculation module

Fig. 4 SASW TEST SYSTEM program

2.2.3 Testing results

In the model test site, all cavities, rocks and pipes are located in 1.5m-2.5m depth. Therefore, the ideal number of sensor spacing is determined 4m. An example of shear wave velocity profile is shown in Fig.5a. The shear wave velocity is around from 180m/s to 250m/s, and it increases with the depth linearly. It is verified successfully that the sample of shear wave velocity profile in case of containing cavity and rock can be identified as shown in Fig. 5b and Fig. 5c.



(a) Standard S-wave profile (b) S-wave profile with cavity (c) S-wave profile with rock

Fig. 5 Shear wave velocity profile

In Fig. 5, a noticeable of S-wave difference between the case of cavity and case of rock is clarified so that the velocity of shear wave decreases when travelling through them. However, it is found that in the rock case, there are many reflections of shear waves in the top of the rock.

3. CONCLUTION

SASW method is a Non-Destructive Testing method that is cheap and easy to operate for checking the soil properties and elastic modulus. It is verified successfully in this study that the SASW method can be successfully applied to the ground with cavity.

Acknowledgement

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Reference

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