2017 년도 한국철도학회 춘계학술대회 논문집 KSR2017S169

Application of Multiple SASW Technique to Investigate Cavity Existence under Asphalt Pavement

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Abstract This paper describes an experimental investigation for investigating cavity under the urban asphalt pavement. The cavity may appear in construction process or generate due to spilling of water from broken or old sewage pipes. Multiple SASW is a non-destructive method that uses Rayleigh waves to determine shear velocity (Vs) profile with depth in the soil. The Vs profile can explain homogenous level of the soil. In this study, it was verified that cavities could be checked by investigating shear velocity profile with depth which is produced by multiple SASW technique. A cavity in the soil generates lower shear wave velocity than that of surrounding soil. In this study, a 2D shear velocity profiles obtained by ABAQUS FE analysis and from the multiple SASW tests performed in Yong-in model site are used for verification of cavity in the soil. It was successfully verified that multiple SASW technique be used for investigating cavity in the soil

***Keywords* :** MASW, cavity, Asphalt pavement, soil profile, shear wave velocity

1. INTRODUCTION

The Multiple SASW (M-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 M-SASW for detecting cavity in the urban asphalt pavement is introduced and tested in ABAQUS modeling for verifying purpose.

2. THEORY

2.1 SASW Testing Method

2.1.1Theory

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Shear and compression waves are the two main modes of propagation of 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. Wave speeds of these different kinds of waves are governed by two different types of modulus. Shear waves of varying wavelengths penetrate into different depths and travel at the velocity of the mediums into which they are travelling.

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].

$$V_{ph} = \frac{360 * f}{\beta} \tag{1}$$

$$\lambda_{ph} = \frac{V_{ph}}{f} \tag{2}$$

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:

$$V_s = 0.92 V_{ph} \tag{3}$$

$$z \approx \frac{\lambda_{ph}}{2} \tag{4}$$

The spacing between 2 geophones (*L*) is dependent on the longest wavelength that can be analyzed. A common criteria is that the maximum wavelength that can be analyzed, with highest possible accuracy, is approximately equal to the length of the receiver spread (Park & Carnevale,2010):

$$\lambda_{\max} \approx L \tag{5}$$

Therefore, the maximum depth that can be obtain is:

$$z_{\max} \approx 0.5L \tag{6}$$

3. Simulation of M-SASW by ABAQUS

3.1 Modeling

The model is simulated in two dimensions (2D), and its size is 8m wide and 15m high with 7 different layers. Thickness of each layer is modeled as 1m. In order to check the effect of cavity existence to the 2D soil stiffness profile, the cavity is simulated to be located at the center of model finite element mesh as shown in Fig. 1. Cavity positions are changed gradually for different case studies.

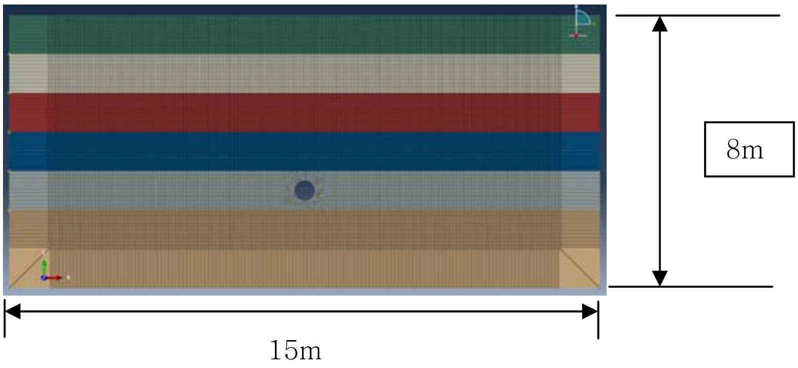

Fig. 1 Abaqus 2D modeling

Impact load applied to the surface of the ground for testing M-SASW is model as a half sine curve function as shown in Fig.2. Loading duration is assumed as about 0.004 sec. The maximum applied impact load was 80N.

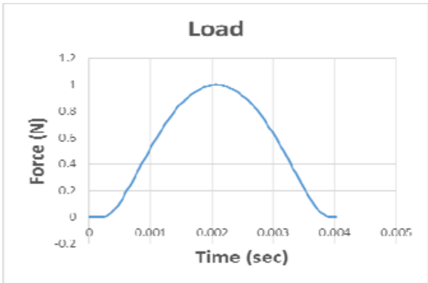

Fig. 2 Haft sin impact load

3.2 Results of ABAQUS FE analysis of M-SASW

Firstly, at each distances described from the position of impact load, waves generated were obtained with time as depicted in Fig. 2. Using those waves with time at each distances presumed as sensor (geophone) located, shear velocity profiles with depth were obtained for cases with cavity and without cavity underneath the asphalt pavement. Next, all shear velocity profiles were converted into color banded values as shown in Fig.3 and Fig.4. In the non-cavity case, 2D shear-wave profile increased with depth smoothly and like hyperbola. Also, it was easy to figure out each layer by checking shear velocity profile as prescribed in the FEA model. However, in the cavity case, 2D shear-wave profile is irregularly distributed with depth and is more complex to be discriminated. The layer's shear velocity with cavity is more distorted than that of non-cavity case.

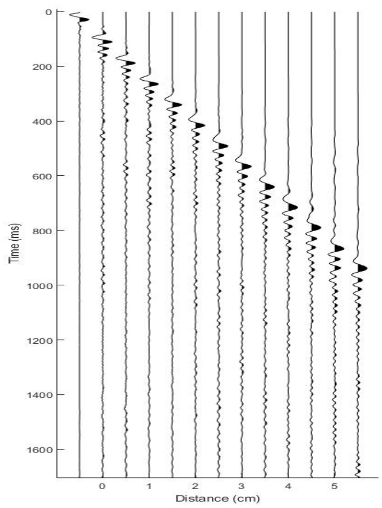

Fig. 2 Obtained velocity results from ABAQUS

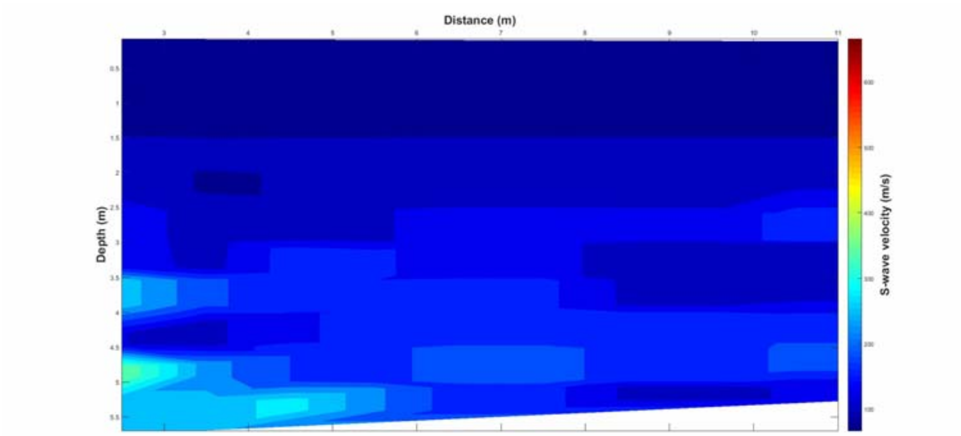

Fig. 3 FE analyzed results from ABAQUS – No cavity: V_s profile with depth

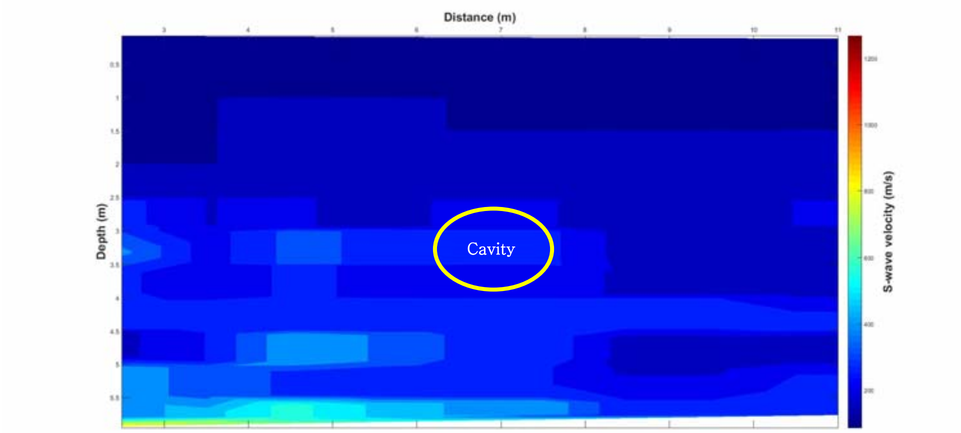

Fig. 4 FE analyzed results from ABAQUS – with cavity of 3m diameter: V_s profile with depth

4. CONCLUTION

M-SASW method is a Non-Destructive Testing method that can be applied to the ground in order to investigate cavity existence under the urban asphalt pavement. In this study, a newly design M-SASW technique was simulated by FEA. It was successfully confirmed in this study that the new M-SASW technique be applied to the ground under asphalt pavement section for checking cavity existence.

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