DETECTION OF CAVITY UNDER A CONCRETE BOX TUNNEL

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DETECTION OF CAVITY UNDER A CONCRETE BOX TUNNEL BY NONDESTRUCTIVE FRACTAL TEST

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ABSTRACT

An innovative, quick and accurate investigation techniques for detecting cavity under pavement concrete slab becomes significant in order to avoid the concrete slab pavement problems during its service-life. Problems of concrete pavement can be due to two basic causes, i.e, deterioration or deficiency of the pavement, e.g., cracks; and the structural adequacy of the pavement and base structure e.g. cavities in concrete slab and deflection causing settlement. In this research, an improved technique for detecting cavity under concrete box tunnel based on nondestructive Flexural-Rigidity Assessment Technique of Concrete Tracks by Anti-symmetric Lamb Waves (FRACTAL) was proposed. The research was carried out at an concrete box tunnel in Seoul. An appropriate non-destructive technique for investigating at the pavement under concrete box tunnel on the existing pavement should meet the requirement of speed and reliability in field testing. Therefore, flexural rigidity was chosen as a key parameter to assess the structural integrity of a concrete box tunnel, rather than material stiffness. The testing results indicate that the FRACTAL technique is able to detect cavities under the concrete box tunnel.

I. INTRODUCTION

The demands for assuring the safety and the performance of pavement under concrete box tunnel requires as non-invasive as possible inspections in order to estimate the physical and structural conditions of in-service structures. The phenomenon of damage from a physical point of view represents surface discontinuities in the form of cracks, or volume discontinuities in the form of cavities. It is very difficult to investigate a damaged element since the cracks or interior defects cannot be visually identified. Therefore becomes necessary to non-destructively assess of

the deteriorated state of the pavement under concrete box tunnel in order to early-evaluation of cavities.

Cavity under concrete box tunnel pavement slab is the emergence of cavity between the face slab and the base, which is structural destruction of road pavement. The emergence of cavity is detrimental to the forces of slab, especially to the edge ad corner of slab. The forced state of slab is similar with cantilever, which may lead to excessive stress and strain and is easy to damages like fracture and crushing. It will seriously affect the service performance and fatigue life of pavement slab.

In recent years, cavities under concrete box tunnel have been found in some road in South of Korea. Five large underground hollows were discovered underneath one of Seoul's road tunnels (http://koreaherald.com).The newly found cavities are large enough to contain stacks of cars. They are located only a few meters away from two similar cavities discovered earlier on August 2014 below the Seokchon tunnel roadway in eastern Seoul.

A quick and efficient of the Flexure Rigidity Assessment Technique of Concrete Tracks by Anti-symmetric Lamb Waves (FRACTAL) is proposed from this study to measure non-destructively the stiffness of concrete pavement. This paper attempts to identify the cavity under concrete box tunnel using NDT Fractal Technique.

II. FRACTAL TECHNIQUE

The FRACTAL technique, which is used to measure the Lamb-wave velocity as an indicator of flexural rigidity in a plate, is also employed to investigate the integrity of the pavement under concrete box tunnel. Determination of the Lamb-wave velocity by the FRACTAL technique is based on the phase difference between two receivers, which is the same procedure employed for the SASW method. Unlike the SASW method, the FRACTAL technique utilizes only the phase-angle information for the Lamb-wave mode, which corresponds to the region of frequencies below the threshold frequency of mode conversion from Lamb wave to Rayleigh wave (Cho, et.al, 1986).

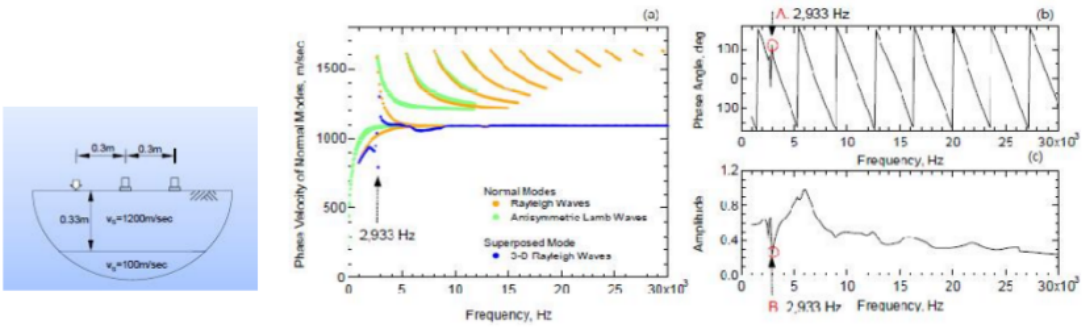


Figure 1. 2-D representation of phase velocity of Lamb wave

Figure 1 shows the agreement between the fundamental modes of Rayleigh waves and Lamb waves at frequency 0 – 3000Hz. Lamb wave can be determined by even surface-waves test. The difference between two modes is attributed to the subgrade stiffness considered in Rayleigh wave method. The frequency below discontinuity 2.993 Hz (A and B) is Lamb wave.

III. INVESTIGATION OF CAVITY UNDER CONCRETE PAVEMENT

3.1. Analysis Data of Fractal Test

Fractal Rigidity Assessment Technique of Concrete Tracks by Anti-symmetric Lamb Waves (FRACTAL) can be used to evaluate the stiffness of concrete slabs resting on subgrade. Cho et al. (3) originally developed the FRACTAL technique. They used the FRACTAL technique to assess the potential deflection of concrete tracks by measuring the flexural rigidity of concrete railroad tracks.

In the FRACTAL technique, the flexural rigidity of concrete tracks is evaluated by means of anti-symmetric Lamb-wave velocities. In Figure 2(a)FRACTAL tests, one impact source and two accelerometers are employed in the measurement. In this study, SASW method set up configuration was employed to collect the seismic surface wave propagation data in pavement site. A impact hammer sources was used to generate R waves on the soil surface. The propagation of the waves was detected using two receiving geophones and the analog signals were then transmitted to a spectrum analyzer which consisted of acquisition box and transferred digitally to a notebook computer. The geophone receivers are deployed at interval 2m with 8m source offset from the first receiver. The Results from FRACTAL tests are summarized in phase spectrum corresponding to Lamb-wave velocity dispersion curve, as shown in Figure 2b and 2c.The principle of the FRACTAL technique, which is that the flexural rigidity of concrete under path can be evaluated by means of Lamb-wave velocities, is presented in Figure 2c. Measurement on concrete slab with wavelength

between 3m and 8 m finds a Lamb-wave velocity between 1000 to 1500 m/sec. Whereas, for wavelength higher than 8 m produces Lamb-wave velocities less than 1000 m/sec.

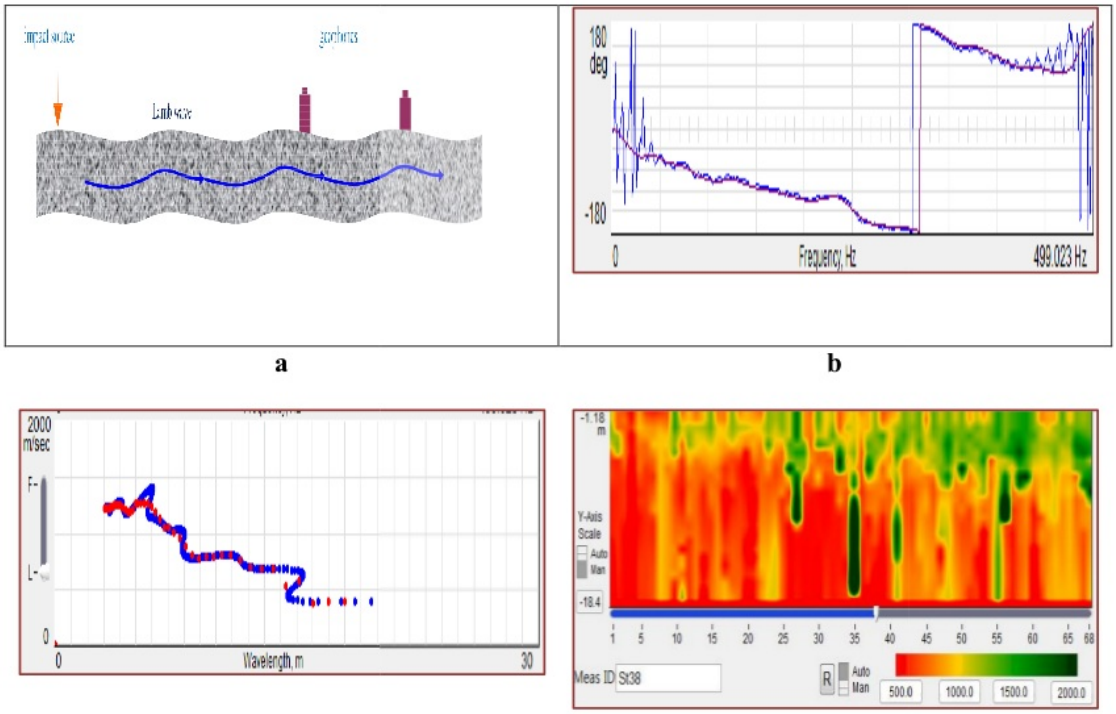
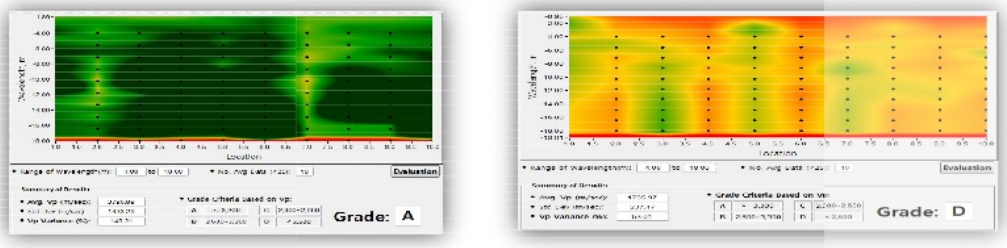


Figure 2. a. Flexural-Rigidity Assessment Technique of Concrete Tracks by Anti-Symmetric Lamb Waves. b. Phase difference spectra for Lamb wave measured by FRACTAL tests. c. Wave length for Lamb wave measured by FRACTAL tests. d. 2-D representation of Lamb wave velocities measured by FRACTAL

3.2. Set Criteria for FRACTAL Test Data Interpretation

The results from data analysis of the tests performed under concrete box tunnel can be illustrated in Figure 3a and 3b. The criterion of Lamb wave velocity was measured at wavelength between 4m to 18 m. From Figure 3b, it was found that the cavities under concrete box tunnel were found with the P wave velocity of 1,756 m/sec and Lamb wave can be detected with velocity of 1,020 m/sec. On the other hand, Figure 3 shows the P and Lamb wave velocity were found to be 3,790m/sec and 2,166 m/sec, respectively. It was indicated no cavity under concrete box tunnel.



a b

Figure 3 a. The result of FRACTAL test without cavity under concrete box tunnel. b. The result of FRACTAL test with cavity under concrete box tunnel

3.3. Application of fractal under concrete box tunnel in Seoul

FRACTAL test was performed in the road-pavement under concrete box tunnel in Seoul. The location of the test can be seen in Figure 5.

Figure 4. Location of FRACTAL test

The test was conducted in Northern side lane 1(UR-NW1: 0 ~ 328 m,), Northern side lane 2(UR-NE2: 0 ~ 136 m, UR-NW2: 0 ~ 28 m, 44 ~ 72 m, 85 ~ 254 m) and Southern side lane 2(UR-SW2A: 0 ~ 132 m, UR-SW2B: 0 ~ 218 m, and UR-SE: 0 ~ 218 m). FRACTAL tests were carried out with 2m geophones interval and performed continuously along the longitudinal axis of the concrete road and a measurement array is overlapped with an adjacent array by 2 m.

3.4. Fractal evaluation for the pavement under concrete box tunnel in Seoul

The Fractal results were presented in Figure 5. Figure 5a shows the Lamb-wave velocities at Northern side lane 1, the section from 0 – 328m with contour color of lime green to red which the Lamb waves velocity was found to be 1,020 m/sec and below. It indicates that the pavement under concrete box tunnel have cavities in pavement layer. In Figure 5b, the section at Northern side lane 2 with the interval between 0m – 136m and 85m – 254m also show that the Lamb waves velocity was found to be less than 1.020 m/sec. It also can be identified that cavities occurred in under concrete box tunnel. On the other hand, the section between 0 – 28m and 44 – 72 m have Lamb waves velocity more than 1000 m/sec where there are no cavity under concrete box tunnel. The Figure 5c shows the Lamb waves velocity in Southern side lane 2. UR-SE2 area with section more than 115m shows the Lamb waves velocity less than 1,020 m/sec. Also, UR-SW2B areas with interval 120m to 135m and 160m to 206m have the Lamb waves velocity less than 1,020m/sec. The potential of cavities are detected on those sections.

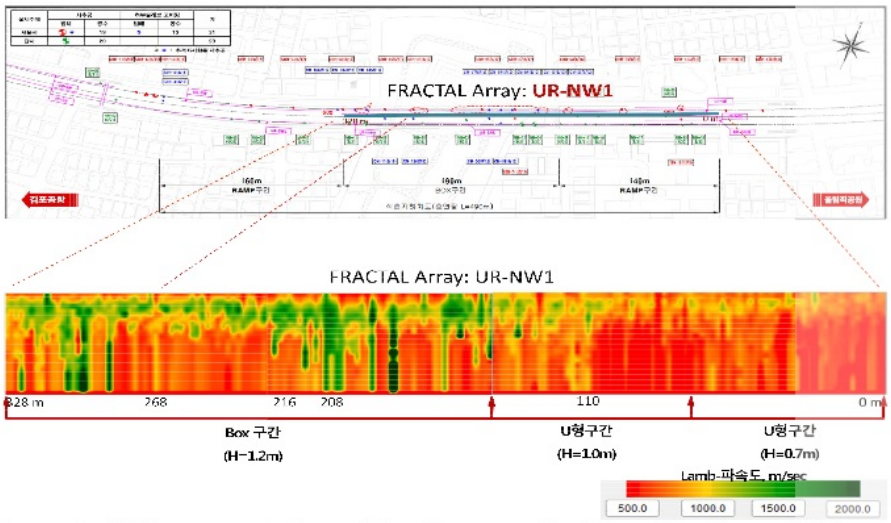


Figure 5a. 2-D representation of Lamb-wave velocities at Northern side lane 1

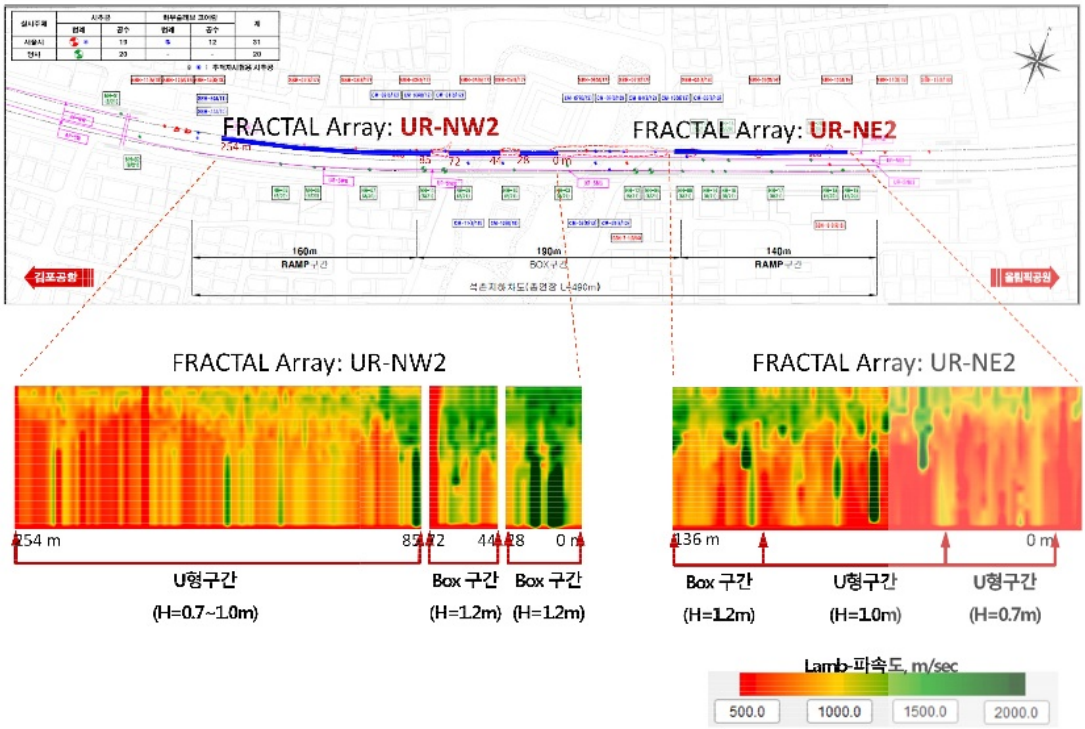


Figure 5b. 2-D representation of Lamb-wave velocities at Northern side lane 2

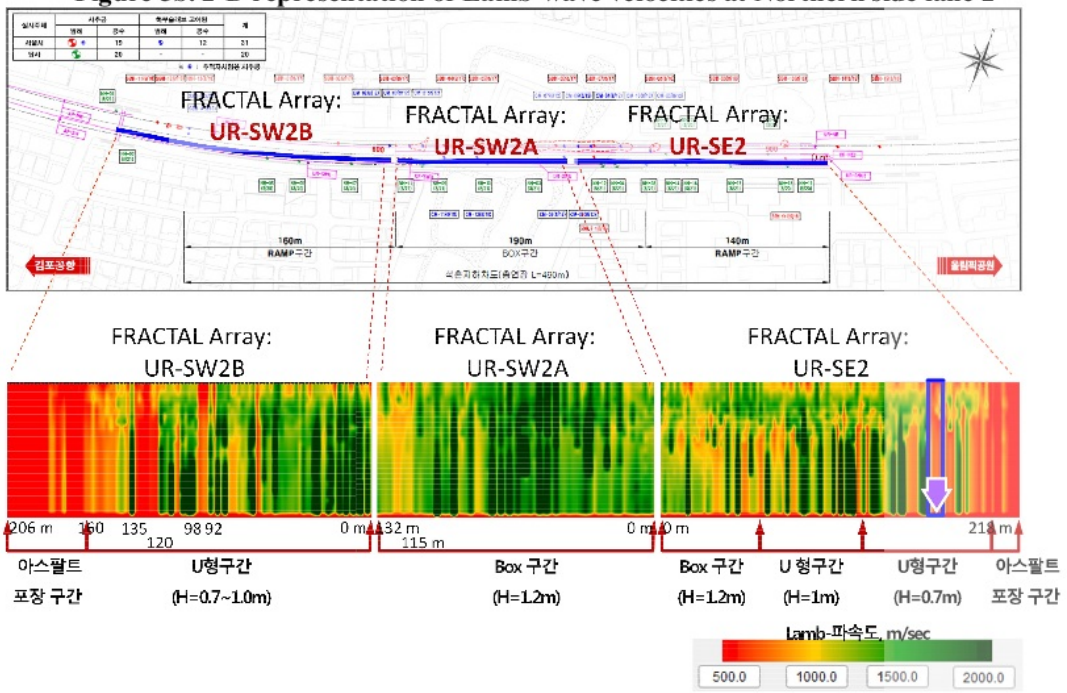


Figure 5c. 2-D representation of Lamb-wave velocities at Southern side lane 2

IV. CONCLUSIONS

In this paper, a practice for identifying cavity under concrete box tunnel was established. This technique is based on the flexural rigidity of a concrete under path. The findings from this study are as follows:

1. The FRACTAL technique was found to be a non-destructively and potential technique used for identifying cavity in pavement concrete under path.
2. From the results of FRACTAL test at Northern side lane 1, lane 2 and Southern side lane 2 in pavement concrete under path in Seoul shows that the cavities was found with Lamb wave velocity less than 1,020 m/s. The Lamb wave velocity below1.020 m/s indicates that there is cavity inside of concrete under path.

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