Full scale simulation of road collapse using accelerated pavement testing

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ABSTRACT: More than 600 cavities underneath the road have been recently discovered in the city of Seoul using ground penetrating radar testing. Various types of cavities will affect the settlement of pavement structures with time and traffic passage. The objective of this study is to simulate the full- scale road collapse due to the occurrence of cavity using accelerated pavement testing (APT). A cubic shape of cavity was installed at depth of 0.3m from the surface in the testbed. The cavity was made of ice with 1m*1m*1m of dimension and the thicknesses of asphalt and base layer were 0.2m and 0.3m, respectively. An 80kN of APT wheel loading was applied on pavement section with 10km/h of speed. Strain gauges were also installed at the bottom of asphalt layer to measure the tensile strain at cavity and intact section. It is observed from this testing that the subbase material initially started to fall off from the bottom of asphalt layer. After then, the cracks initiate at the bottom of asphalt layer with settlement of pavement surface. Finally, the width of crack increases with number of load application and the permanent deformation is found to be 130mm at 6,000 of load application. It is also found from strain measurements that the tensile strain values at cavity section are two times greater than those at intact section.

Keywords: Road Collapse, Accelerated Pavement Testing, Full Scale Simulation

1 INTRODUCTION

The road collapse frequently occurred in urban area of Seoul tends to threaten the safety of road users and induce the anxiety of people. Main causes of road collapse from the forensic investigation are found to be due to the underground construction, leakage of drain pipe, and other excavation work. Various researches have been focused to investigate the cause and mechanism of these road collapses. Multi-channel ground penetrating radar has been used to detect the cavities under the pavement in main road sections of Seoul. Based on GPR test results, a lot of cavities are located at 0.2~0.4m from the surface of pavement, which is at the bottom of asphalt layer or on top of subbase layer (Seoul Metropolitan Government, 2005).

The time of occurrence in road collapse is normally dependent on the size and location of cavities, traffic volume, soil condition, and environment condition. Recently, Japan has experienced a large amount of road cavities due to the earthquake. As shown in Table 1, they suggested the risk criteria of road collapse using the width and depth of cavities. Since this criteria is not based on the scientific analysis or experiment but the extensive experience in the field, it is necessary to establish the quantitative criteria for the road collapse by considering the various factors such as soil condition, climate, and traffic volume.

Table 1. Risk Criteria of Road Collapse in Japan

Risk Rank	Risk Criteria	Action Plan
A	Less than 0.3m depth or more than 0.3m depth with cavity width more than 1.5m	Urgent Repair
B	More than 0.3m depth with cavity width 0.5~1.5m and refer the graph in case of cavity width more than 1.5m	Normal Repair (Repair before wet season)
C	More than 0.3m depth with cavity width less than 0.5m and refer graph in case of cavity width more than 0.5m	Regular Monitoring

2 CONSTRUCTION OF TESTBED

A full-scale testbed for accelerated pavement testing was constructed in the KICT. It will be utilized to figure out the relationship between road cavity and pavement distress and validate the road collapse model developed by laboratory testing and numerical analysis in the KICT. Cross and plane view of APT testbed are shown in Figures 1 and 2.

The length and width of APT testbed are 10m and 3m, respectively. The APT testbed consists of 200 mm of an AC layer with the conventional asphalt mixture and 500 mm of aggregate base over the subgrade. This testbed has two pavement sections to install the artificial cavities in different depths. Two 500*500*300mm size of artificial cavities are installed at 300mm (Section A) and 700mm (Section B) from top of pavement surface. Section 1 and 2 correspond to the rank A and B, respectively, based on the Japanese risk criteria of road collapse. The intact section without road cavities was used to measure the pavement response under the APT loading and monitor the pavement distresses for comparison with cavity sections

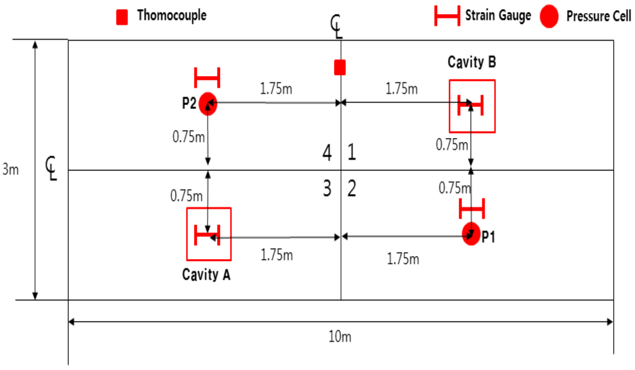

Figure 1. Plane View of APT Testbed

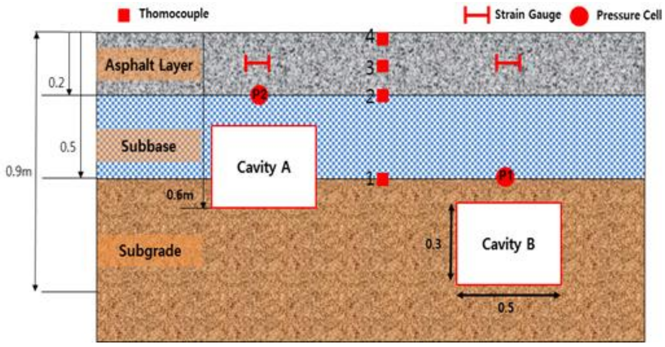

Figure 2. Sectional View of APT Testbed

3 CONSTRUCTION OF TESTBED

To estimate the difference of pavement structural capacity between cavity and intact sections, the falling weight deflectometer(FWD) test was used in this study.

3.1 *FWD Testing*

In order to estimate the reduction of structural capacity due to occurrence of road cavity, the FWD testing was conducted on both intact and cavity sections (Ullidtz, 1995). A 24kN of FWD loading was applied on pavement surface at 20C of temperature. Figure 4 presents the FWD deflection basins obtained from intact and cavity A sections. It is found from this test that center deflection in cavity A section is 10% higher than that in intact section. However, deflections at 1500mm from the loading center of both sections are almost same, which there are no difference in structural capacity of subgrade.

The layer modulus of each section has been calculated using the FWD deflections and backcalculation technique. In this study, the GAPAVE program developed by Korea Institute of Civil Engineering and Building Technology was utilized for the backcalculation of layer moduli. The backcalculated layer moduli calculated using GAPAVE program were summarized in the Table 2. It is found that the moduli of asphalt layer and subgrade in intact and cavity sections are the same, but the subbase modulus of cavity section is 25% lower than intact section. It is concluded from FWD testing that increase of center deflection and reduction of subbase modulus is caused by the occurrence of road cavity in subbase layer.

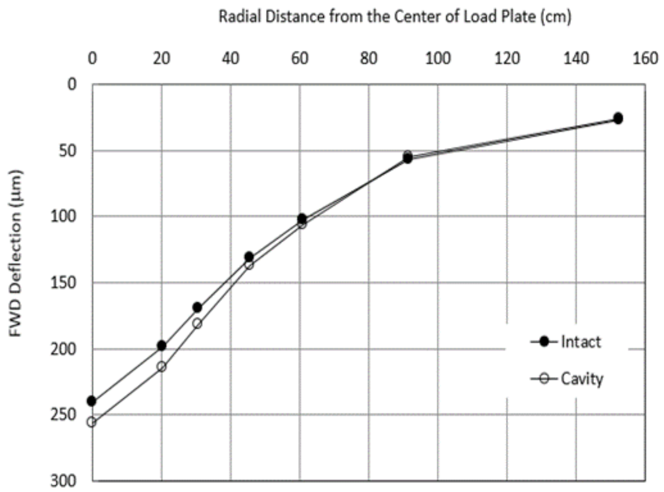

Figure 3. Comparison of FWD Deflection Basin Obtained from Intact and Cavity Sections

Table 2. Results of FWD Backcalculated Modulus in Cavity and Intact Sections

Layer	Cavity Section			Intact Section		
	Mean (MPa)	SD* (MPa)	COV** (%)	Mean (MPa)	SD (MPa)	COV (%)
Asphalt	2742.9	464.9	16.9	2680.1	549.3	20.5
Subbase	105.1	2.4	2.3	129.0	29.4	22.8
Subgrade	60.0	5.2	8.7	62.5	2.8	4.5

SD* : Standard Deviation
COV** : Coefficient of Variation

4 ACCERLATED PAVEMENT TESTING

To estimate the effect of size and location of road cavity on pavement failure, the accelerated pavement testing (APT) was conducted on constructed testbed. An eight ton of APT loading was applied with at speed of 10km/h. The testing temperature was maintained at 25C. The permanent deformation was measured periodically on cavity and intact sections using laser profiler. Figures 4 to 6 show the change of permanent deformation profile measured at given number of load applications. The maximum permanent deformation of intact and Cavity B section are approximately 10mm and 30mm after 90,000 load application, respectively. In case of cavity section A which has cavity at the depth 300mm from the surface, about 900mm of permanent deformation was measured at 32,000 load application which is twenty times higher than cavity section B. It is also found from permanent deformation profile that the shape of intact section is W which can be observed on general asphalt pavement due to the densification of asphalt layer. However, the profile of cavity section is similar to the U shape due to settlement of subbase layer.

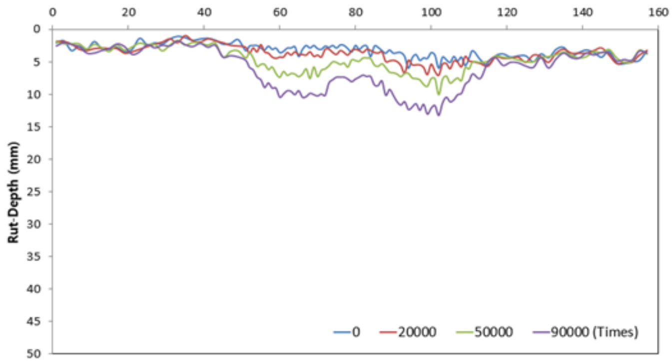

Figure 4. Change of Rut Depth Profile with Number of Load Applications in Intact Section

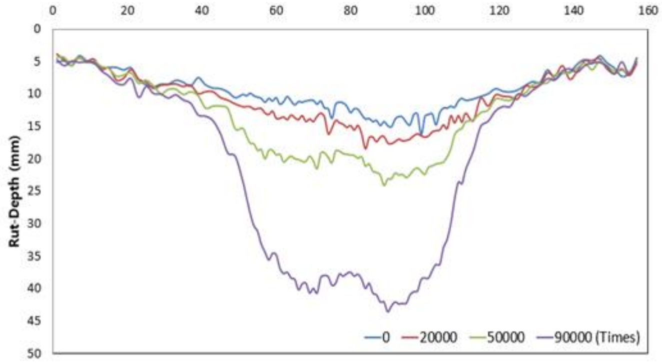

Figure 5. Change of Rut Depth Profile with Number of Load Applications in Cavity B Section

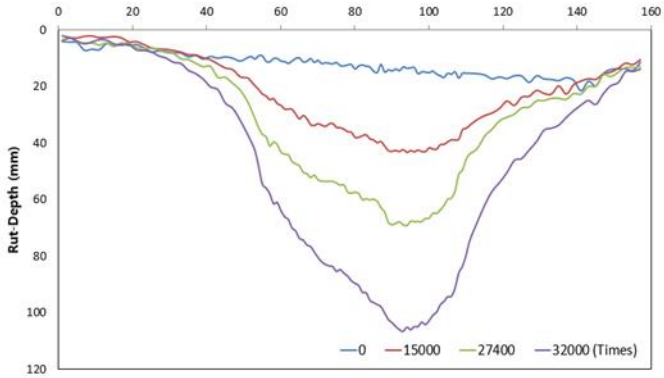

Figure 6. Change of Rut Depth Profile with Number of Load Applications in Cavity A Section

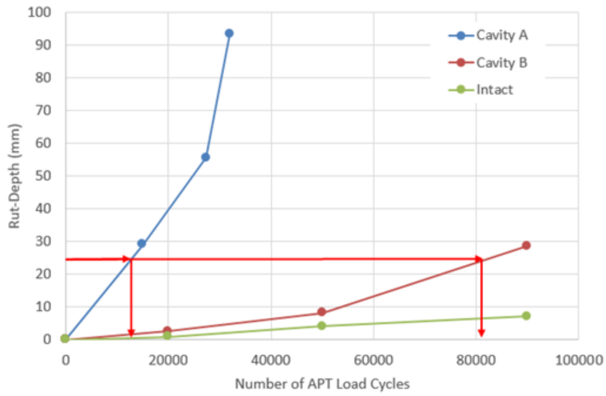

Figure 7. Rut-Depth Measured from Number of APT Load Cycles in Intact and Cavity Sections

Figure 7 presents the change of maximum permanent deformation with number of load repetitions in intact and cavity sections. Assuming that a 25mm of permanent deformation is pavement failure, the number of APT load repetitions at failure condition was determined. It is observed from this graph that the number of load repetitions at failure cavity section A and B are 13,000 and 80,000, respectively. The cavity section A will be failed six times faster than cavity section B.

5 CONCLUSIONS

The final objective of this study is to evaluate the effect of size and depth of cavities on the pavement failure using the full-scale accelerated pavement testing. As a preliminary testing, it is found from FWD testing that the center deflection of cavity section is 10% greater than intact section indicating the 25% reduction of modulus in subbase layer due to the occurrence of cavity. The measured permanent deformation of intact section is approximately is 10mm at 90,000 load repetitions. However, for cavity section of 0.7m depth, the 30mm of permanent deformation was measured at 90,000 load repetitions which is three times greater than intact section. At cavity section of 0.3m, the permanent deformation reached up to about 90mm and the elliptical hole occurred at pavement surface after testing. This paper is intended to figure out the pavement failure mechanism due to occurrence of cavities underneath of pavement using accelerated pavement testing. In the future, the accelerated pavement testing will be conducted at pavement sections with various depth and size of cavities. Test results will be utilized to establish the criteria of risk in road collapse based on the various different conditions.

ACKNOWLEDGEMENT

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