# An analysis of MASW responses for urban ground subsidence

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## SUMMARY

Ground subsidence occurred by sink-hole and cavities in the city has become a serious problem in Korea so these days geophysics survey study for the near-surface become active. Multichannel analysis of surface waves (MASW) is useful survey method to detect anomaly under the subsurface and characterize the structure of S wave velocity of the medium. In this study, we set subsurface seismic model with reference to the real coring data near the sink-hole outbreak point. To define elastic properties of the medium from the core data, we apply ground physics model (GPM) and use Gassman's equation, the typical model for GPM. For Gassman's equation input, we consider and assume rock properties as porosity and bulk modulus and so on. The algorithm for this study is time-domain 2D FDM elastic wave modelling algorithm which is based on staggered grid and it damp the reflected wave in the convolutional perfectly matched layer (CPML) zone. We carry out synthetic modelling experiments with the composited medium model and analyse the sensitivity of the underground cavity effect. To set variables of the cavity, we adjust the scale and the depth of the cavity. MASW modelling results show the effect of the cavity and we will study further for the synthetic experiments.

**Key words:** surface wave, MASW, sink-hole, RPM

## INTRODUCTION

Ground subsidence like sink-hole or cavity within urban areas in South Korea has become serious, making geophysical survey more important for the prevention. Among several geophysical survey methods, multichannel analysis of surface waves (MASW) method, which analyses Rayleigh wave measured by multichannel receivers (usually 24 geophones) can also applicable to the detection of ground subsidence, especially occurring deep subsurface (around 10 m), by exploring subsurface structure of shear wave (S-wave) velocity. In this study, we made an elastic wave model after a big ground subsidence area in Song-Pa-gu, Seoul, South Korea, in which sink-hole occurs most frequently. In order to construct elastic velocity structure of the synthetic model, we use rock physics model (RPM) concept to compute the density, and P- and S-wave velocities of the synthetic model considering the characteristics of the ground: since the ground is not composed of only rock, we call the constructed model as ground physics model (GPM). For the construction of GPM of Song-Pa synthetic model, we use all the information (coring data from boreholes) we can have. In the GPM construction, we first applied RPM equations first: Gassman's equation for rock under water table, while using Wood's equation for the fluid bulk modulus computation, VRH equation for the grain bulk modulus, Nur's equation for the dry rock bulk modulus (Gassman, 1951). For the numerical simulation of MASW survey, we used a two-dimensional (2D) time-domain (TD) finite difference (FD) elastic wave modelling algorithm with convolutional perfectly matched layer (CPML) as the boundary conditions of computation domain.

## MODEL COMPOSITION

For the analysis of MASW responses for subsurface subsidence, we first construct GPM following a sink-hole outbreak spot in Song-Pa-gu, Seoul, South Korea, based on the concept of RPM constructing strategies. For more realistic model generation, we used coring data from borehole within Song-Pa-gu and other available information provided by Seoul geotechnical information data-base system.

Ground water temperature and pressure of the Song-Pa area is 15℃ and 0.1 MPa, respectively and the salinity of water is properly assumed to be zero. The Asphalt on the ground of the area is assumed to have a thickness of 0.1 m, and subsurface is composed of six different soil composition sections along the depth (Figure 1): the first layer is from the bottom of asphalt (0.1 m) to 3 m, the second layer from 3 m to 9 m, the third from 9 m to 14 m, and the fourth from 14 m to 17.5 m, consisting of clay-gravel, sand-gravel, silt-sand and sand-gravel, respectively. Beneath the fourth layer, weathering layer exists with a thickness of 2 m, being relatively thinner than the upper layers overlaying the basement rock of granite. Above the underground water level that is at a depth of 9 m, total moisture content is 0.5; below the underground water level, water saturation is 1. Glover (2013) suggested that the range of porosity values for rocks to assume the porosity; the porosities of clay, sand, gravel, weathering, granite is 0.5, 0.25, 0.2, 0.11, 0.001, respectively, and the porosity is a weighted average value depending on a bulk ratio between quartz and clay when two compositions are mixed in a medium. With this information of ground water and medium, we compute the density, and P- and S-wave velocities of the GPM under consideration (table 1).

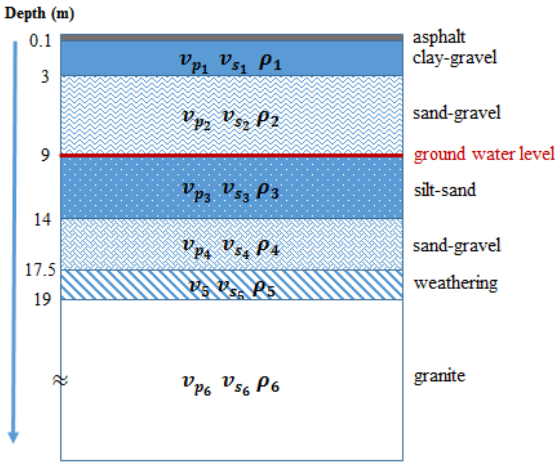


**Figure 1: Geological model used as basis for seismic modelling. The composition of the medium and the elastic proper velocity (Vp), S wave velocity (Vs) and density ($\rho$), are shown for each layer.**

| Depth (m) | Composition | Vp (m/s) | Vs (m/s) | Density (g/m$^3$) |
|---|---|---|---|---|
| **0.1 ~ 3** | Clay-gravel | 2487.2 | 736.1 | 1874.4 |
| **3 ~ 9** | Sand-gravel | 3024.8 | 1287.7 | 2166 |
| **9 ~ 14** | Silt-sand | 1908.6 | 688.2 | 2008.7 |
| **14 ~ 17** | Sand-gravel | 2543.4 | 1255.6 | 2278.3 |
| **17 ~ 19** | Weathering | 3182.7 | 1656 | 2468.3 |
| **19 ~ 40** | granite | 5938.7 | 3977.8 | 2648.3 |

**Table 1: Formation model information for seismic modelling per each layer: Composition, P wave velocity (Vp), S wave velocity (Vs) and density.**

## NUMERICAL MASW SURVEY MODELLING

To perform modelling of MASW survey for the constructed GPM, we used 2D FDTD elastic wave modelling algorithm, which is based on a staggered grid. The reflected wave is damped in the convolutional perfectly matched layer (CPML) zone around the model and the algorithm considers the effect of air on the surface with the condition of free-surface that $z$ axis shear stress is zero.

For modelling of MASW survey, we use a grid size ofs 0.1 m × 0.1 m and CPML zones are set 10. Wavelet source is 20 Hz, low frequency for surface wave survey, and source point is the left side of the geophone array. The closest geophone offset with the source is 10 m and the number of geophones are 50 with 1 m distance each other. In order to analyse the sensitivity of the MASW survey, we set variables a cavity under the ground as the size and the depth of the cavity.

Before simulating numerical experiments, we tested layer model without a cavity under the ground. A displacement section shows boundaries of the layers and the effect of boundaries is dimmed along the depth. Firstly we gave the fundamental scale of the cavity which is 8 m × 5 m and the depth is 10 m. The strong effect appears in the section at the top of the cavity but not the bottom of the cavity.

## CONCLUSIONS

In this study, we construct the so-called ground physics model (GPM) following the concept of rock physics model (RPM) to compute density and P- and S-wave velocities for the numerical simulation of MASW survey. The numerical modelling of MASW survey has been made using 2D FDTD staggered grid elastic wave modelling algorithm with CPML boundary condition. To construct more realistic GPM of subsurface subsidence model, we specifically chose a ground-subsidence occurred area in Song-Pa-gu, Seoul, South Korea. For the construction of corresponding GPM, we used all the available data from Seoul geotechnical information data-base system. We could confirm that modelling results for the GPM of the medium layers of the Song-Pa area sensitive to the boundaries between layers. Further, we can observe a significant highlight at the top of the cavity in the simulation of the cavity. We will further analyse and discuss about the sensitiveness of MASW responses to the cavity in the conference.

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