Geophysical monitoring for inspecting the stability of the sea dike in South Korea

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SUMMARY

Geophysical methods including electrical resistivity and MASW are used for delineating seawater inflow through sea dike and detecting the abnormal compactness region that could affect the structure of dike. To identify the part of anomalous seawater inflow through the sea dike, we periodically carried out 3D resistivity survey along the dike including anomalous regions. 3D resistivity survey and monitoring for the dike can define effectively the low resistivity zones lower than 1 ohm-m, which may indicate seawater inflow through the dike. For detailed analysis of 3D resistivity monitoring data, time-lapse inversion method was adopted in this study. Time-lapse inversion is effective for identifying the subtle changes over time and for suppressing inversion artifact. The results of time-lapse inversion method show no significant changes in the sea dike with time. Shear wave velocity profiles obtained by MASW periodically indicate less compacted layer that could be originated by the loss of dredge sand or the bad compactness condition during the construction and would be predicted the possibilities of subsidence. From this study, 3D electrical resistivity surveys using time-lapse inversion approach and periodic MASW surveys are revealed to be effective for identifying seawater inflow pathway through the sea dike and investigating its safety, respectively.

Key words: sea dike, 3D electrical resistivity, time-lapse inversion, MASW

INTRODUCTION

The detection of anomalous regions at sea dike is a significant duty for preventing the potential structural problems and geophysical approaches are relevant to identify these regions. Among various geophysical methods, resistivity method and MASW (multi-channel analysis of surface wave) are widely used for detecting an anomalous area in underground circumstance. The resistivity method has been widely used to image the electrical properties of the subsurface. 2D resistivity survey has been dominantly applied in the engineering and environmental problems because of the convenience of data acquisition and interpretation.

The 2D resistivity data acquired along the dike are significantly distorted by the strong 3D effect arising from the specific dike geometry (Sjödahl et al., 2006). Theoretically, the 2D resistivity method assumes that there are no physical changes along the strike direction of the subsurface structure. However, the structure of sea dikes does not fulfil this condition particularly when the 2D resistivity survey line is parallel to the dike. This theoretical violation also makes quantitative interpretation difficult (Cho and Yeom, 2007). 3D resistivity survey has been introduced since effective 3D inversion algorithm is available. Furthermore, this method has become suitable for monitoring as field techniques have become more refined and data collection rates increased.

3D resistivity survey is very powerful tool to overcome these problems of 2D resistivity survey. Even though 3D resistivity survey requires too much times and efforts in data acquisition and data processing, it is able to provide a lot of effective information necessary for detecting or monitoring the seawater inflow through sea dike. Moreover, time-lapse inversion method to suppress inversion artefact is more reliable to identify the significant changes compared to the conventional independent inversion (Kim, 2013).

MASW is one of the surface wave exploration methods evaluating ground stiffness under various conditions of geotechnical environments and has two approaches such as active and passive mode. The purpose of MASW survey using active mode in this study is to make shear wave velocity profiles along the sea dike periodically and to compare results for monitoring subsurface regions may induce subsidence that could be originated by the loss of dredge sea sand or the bad compactness condition during the construction. Moreover, N values profiles from SPT (standard penetration test) (Peck et al., 1953) were compared to the shear wave velocity profiles at high and low velocity regions, respectively.

METHOD AND RESULTS

The sea dike in this study was completed in 2006 for water blockage and for constructing the final section in 2008. Length of the dike is 33.9 km, the longest in the world, and average floor width is 290 m having maximum 535 m with 36 m height. The dike was constructed by dredged sea sand after setting up riprap with inside filter to prevent tidal force.

To investigate the anomalous zone along the dike, we conducted the 3D inversion of apparent resistivity data sets acquired along the dike. For all the survey lines, the station spacing was set to 5 m and both dipole-dipole and modified pole-pole array that could enhance the signal-to-noise ratio were simultaneously used. All the 2D apparent resistivity data sets obtained along each survey line were merged and then the merged apparent resistivity data were edited for the 3D inversion. The edited data were inverted by the 3D inversion

program, DC_3DPro (Kim, 2010), which adopt a well known iterative least-squares method based on the finite element modelling. To avoid the numerical error in the forward modelling, the mesh system in which the number of elements between two adjacent electrodes is at least four was established and each inversion block to have four modelling elements along the horizontal axis and two or four elements along the depth axis was set. In the least-squares inversion, the regularization parameter is required to obtain a stable and geologically reasonable solution. The 3D inversion program used in this study adopts a smoothness constraint algorithm with ACB technique (Yi et al., 2003), in which the regularization parameter is automatically determined through the analysis of the parameter resolution matrix and its spread function during the inversion process and time-lapse inversion technique.

Figure 1 shows 3D inversion results with percent change using time-lapse data sets using the independent inversion and time-lapse inversion, respectively. Percent changes of resistivity during one month from the different two inversion methods show the drastic change spatially and the little variation with time, respectively. Since the variation of subsurface conditions would not be changed for the short period, time-lapse inversion would be more effective compared to the independent inversion that could be contaminated by noises.

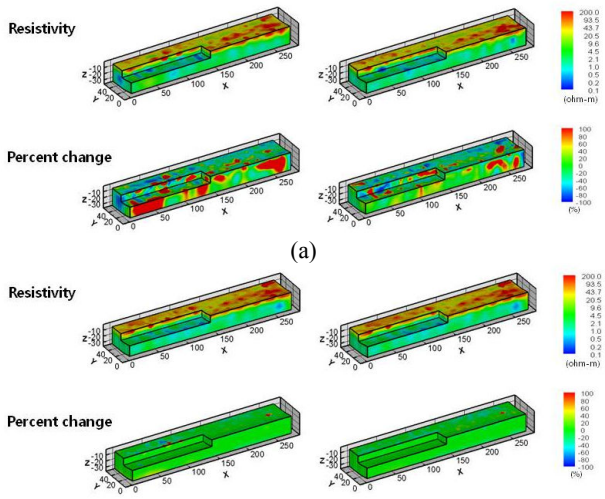

Figure 1. 3D resistivity distribution from the independent inversion (a) and the time-lapse inversion (b) with the percent-change from the time-lapse data set obtained on August 23 (left column) and September 26 (right column), 2012, respectively.

Figure 2 indicates MASW inversion results showing shear wave velocity structure of subsurface periodically and their results compared to N values profile from SPT at low and high velocity area, respectively. Low wave velocity regions lee than 130 m/sec still remain but slightly higher after 6 months near No.17+66 and high velocity region is near No.17+50. N values profile from SPT with depth on November 2012 at two points indicate that the relatively high N values profile (higher than 10 blows per 30cm) coincide high shear wave velocity region while low N values profile (lower than 4 blows per 30cm) especially depth ranging from 4 to 8 meters well matches the depth of low velocity region.

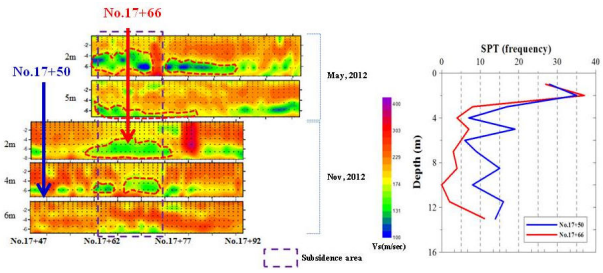

Figure 2. Shear wave velocity profiles from periodic MASW survey with N values profiles from SPT at 2 points.

CONCLUSIONS

3D resistivity survey using time-lapse inversion method and MASW survey with SPT profiles were applied periodically to monitor the anomalous subsurface condition including seawater inflow regions through the sea dike and the expected regions of subsidence. From the 3D resistivity inversion approach, time-lapse inversion proved to be more effective compared to the independent affecting by inversion artefact. Moreover, shear wave velocity profiles from MASW survey compared to N values profiles from SPT are revealed to be well matched the regions of abnormal compactness and would be suitable to predict the potential subsidence area.

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