APPLICATION OF 2D AMBIENT NOISE TOMOGRAPHY TO LEVEE SAFETY ASSESSMENT IN NEW ORLEANS

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Abstract

Geophysical investigations were carried out at three sites along levees in the New Orleans area. The sites sustained damage from Hurricane Katrina in 2005 and have since been rebuilt. The geophysical methods include active and passive surface wave methods, and capacitively coupled resistivity. This paper summarizes data acquisition and analysis of 2D passive surface wave data. Twelve cableless seismic data acquisition units with vertical component 2 Hz geophones were used to record ambient noise data. Each unit includes a GPS clock so that all units can be synchronized over any distance without cables. Data acquisition used a linear array with geophone spacing of 5 m and four geophones were moved up forward every 10 min. along 450 ~ 1,100 m length lines. Total data acquisition took several hours for each line. Recorded ambient noise data were processed using the common midpoint spatial autocorrelation method (CMP-SPAC) and clear dispersion curves were obtained at all sites. Minimum frequency ranges from 1 to 2 Hz and maximum frequency ranges from 10 to 30 Hz depending on site. Obtained dispersion curves are generally consistent with those obtained from active surface wave methods and L-shaped arrays. Non-linear inversion was performed and 2D S-wave velocity (V_S) models were obtained. The method penetrated to a depth of 40 ~ 60 m and provided 450 ~ 1100 m cross sections along levees. The interpretation focused on identifying zones beneath the levees or canal walls having low V_S, corresponding to saturated, unconsolidated sands or low-rigidity clays. Resultant V_S profiles are generally consistent with existing drilling logs and the results of laboratory tests.

Site of Investigation

In 2005, the Hurricane Katrina hit New Orleans and killed more than 1,000 people. During the Hurricane, the levees along several drainage canals collapsed and caused serious flooding (Nelson, 2015). A large area of New Orleans was flooded by more than 2 m of water and most of damage from the Hurricane was due to flooding. Geophysical investigation was carried out at three sites, Industrial Canal, London Avenue Canal, and 17th Street Canal, where levees collapsed and caused serious floods (Figure 1). Except the Industrial Canal where levee collapsed by over topping, the levee at the London Avenue Canal and 17th Street Canal broke before water reached top of the levee. At the London Avenue Canal, piping due to a soft sand layer, at the 17th Street Canal, shear failure due to a soft organic clay layer, caused levees to break respectively. The geophysical investigations were carried out to delineate the extend of the soft sand and clay layers beneath the levees. The geophysical methods include active and passive surface wave methods, and capacitively coupled resistivity. This paper summarizes data acquisition and analysis of surface wave data, 2D continuous shallow investigation and 1D deep investigations.

2D Continuous Shallow Investigation Using Ambient Noise Tomography

Measurements were carried out on survey lines of 450~1,100 m at toe of levees at three investigation sites. Twelve Geometrics Atom cableless seismic data acquisition units with vertical

Figure 1: Site of investigation.

Figure 2: Schematic diagram of data acquisition.

component 2 Hz geophones were used to record ambient noise data. Each unit includes a GPS clock so that all units can be synchronized over any distance without cables. Data acquisition used a linear array with geophone spacing of 5 m and four geophones were moved up forward every 10 minutes. Figure 2 shows the schematic diagram of data acquisition. Data acquisition of 450～1,100 m lines took several hours by one to three people. Ambient noise data was processed in terms of CMP-SPAC (Hayashi et al., 2015) method. Authors use the term "Ambient noise tomography" to refer to the passive surface wave method analyzed with CMP-SPAC method. Figure 3 shows examples of coherencies (a) and phase velocity images in frequency domain (b) obtained at the survey line along the 17th Street Canal. We can see that clear coherencies and dispersion curve were obtained.

Figure 4 compares dispersion curve obtained from CMP-SPAC method using a linear array with those obtained from active surface wave method using a sledge hammer and passive surface wave method using a large L-shaped array mentioned later along the Industrial Canal. The dispersion curve obtained from a linear array agreed with one obtained from an L-shaped array. It also agreed with one obtained

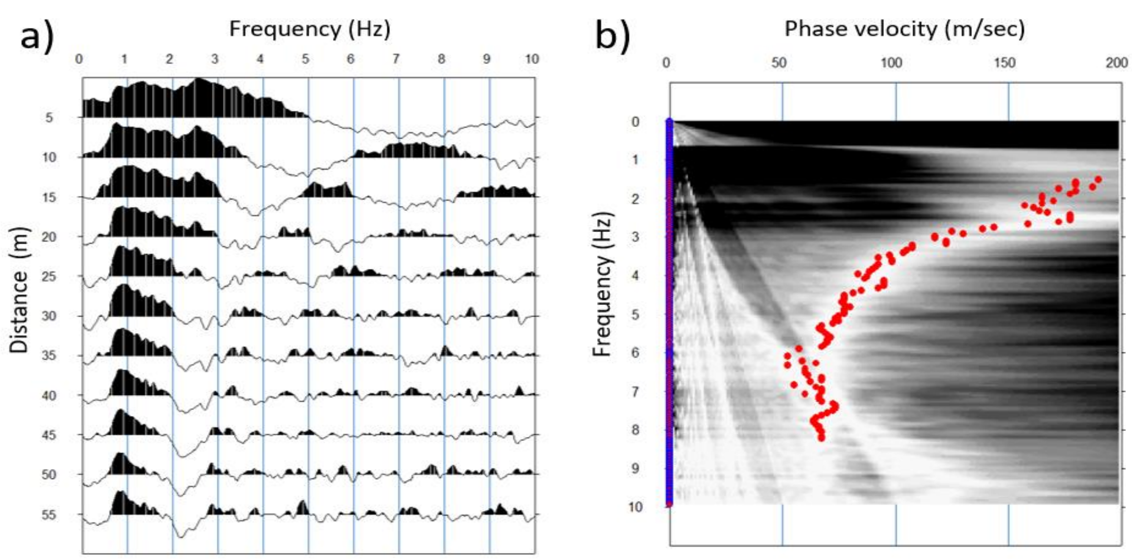

Figure 3: Coherencies (a) and phase velocity image in frequency domain (b) obtained at 17th Street Canal.

from the active method above a frequency of 10 Hz. As a rule of thumb, the penetration depth of the surface wave method is about one-half to one-third of the maximum Rayleigh wave wavelength (e.g. Xia et al., 1999). The maximum wave length obtained from the linear array is approximately 200 m and it implies that V_S to a depth of 50 m can be estimated.

Figure 5 shows a V_S cross section obtained from ambient noise tomography at the Industrial Canal. There is a high velocity zone at a depth of 10 m between distance of 350~750m that corresponds to a section where levee collapsed. It appears that the rebuilt of levee caused the high velocity zone.

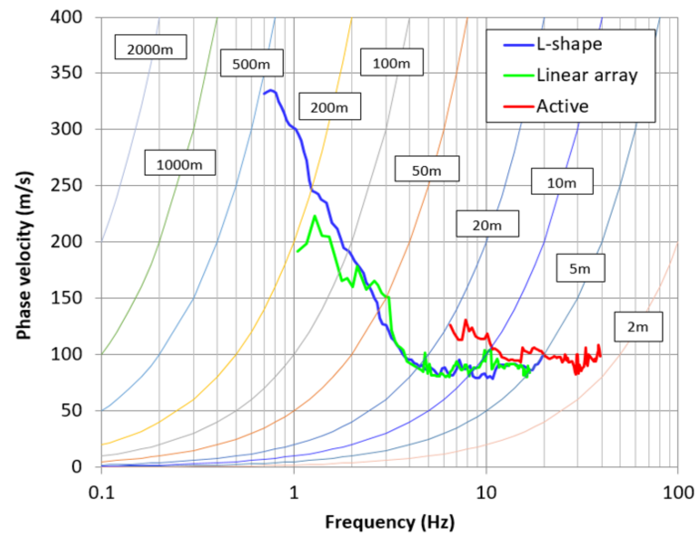

Figure 4: Comparison of dispersion curves at Industrial Canal.

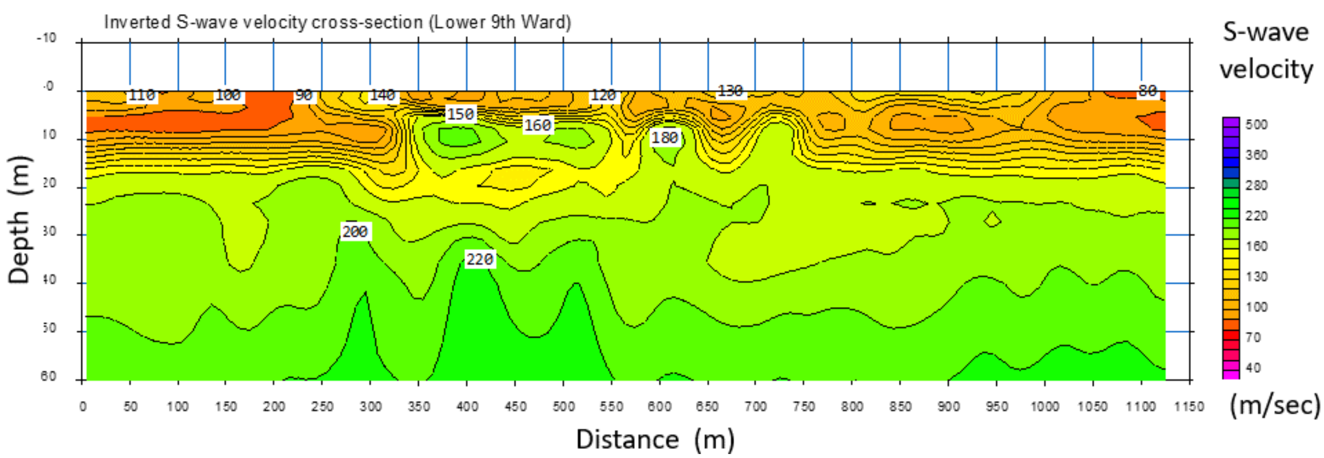

Figure 5: V_S cross section obtained from ambient noise tomography at the Industrial Canal.

1D Deep Investigation Using Large L-shaped Arrays

One dimensional microtremor array measurements using large L-shaped arrays were performed to evaluate the applicability of linear array and to investigate deeper structures. Three different size (15, 60 and 240 m) of L-shaped arrays were used in the measurements (Figure 7). The same seismographs and geophones were used and geophone spacing varies from 5 to 340 m. Figure 6 summarizes dispersion curves (a) and analyzed V_S profiles (b) at three sites. V_S was estimated to a depth of 150 ~ 400 m depending on the sites.

Comparison with Existed Drilling Logs

Figure 8 overlays V_S profiles obtained from ambient noise tomography on soil profiles estimated from drilling logs (Duncan et al., 2008) at the London Avenue Canal and the 17th Street Canal. As mentioned above, piping due to a soft sand layer and shear failure due to a soft organic clay layer caused

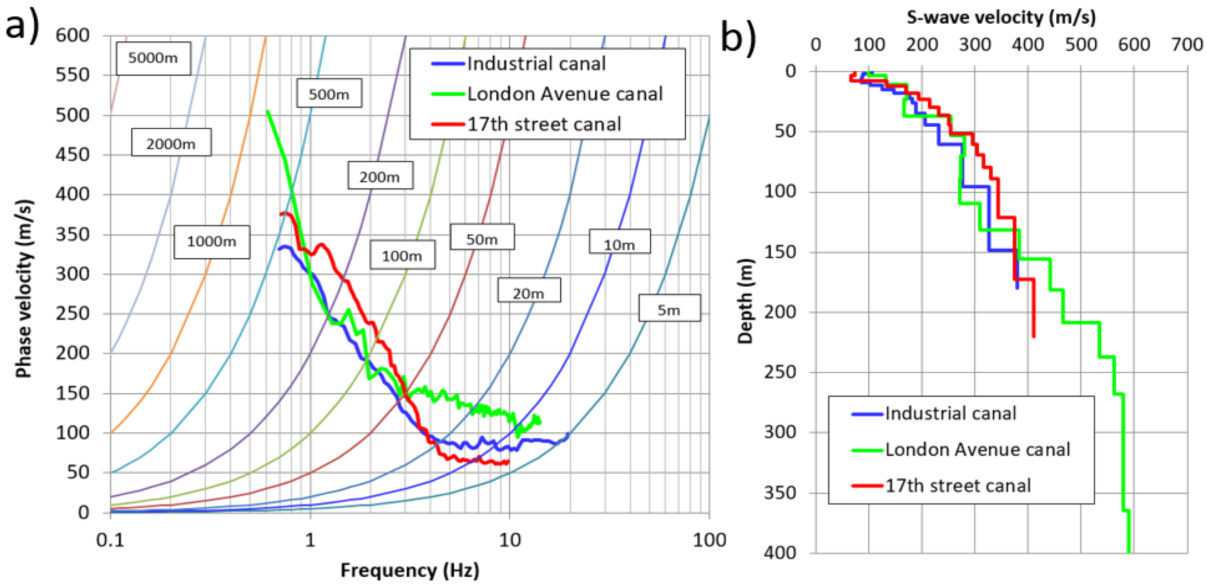

Figure 6: Dispersion curves as measured using L-shaped arrays and deep S-wave velocity profiles at three sites.

Figure 7: Configuration of L-shaped arrays for 1D deep investigation at the Industrial Canal.

levee collapse at the London Avenue Canal and the 17th Street Canal respectively. V_S corresponding to the sand layer beneath the London Avenue Canal and the clay layer beneath the 17th Street Canal are 130 m/s and 170 m/s respectively and they imply that the sand and clay layers were very soft and might cause geotechnical problem related to the levee collapse.

Conclusions

V_S structures along the levees collapsed by Hurricane Katrina were estimated from ambient noise tomography. The results showed that cableless seismographs and linear arrays could simply and quickly estimate the V_S cross sections to a depth of 50 m. Resultant V_S structures were generally consistent with soil profiles estimated from drilling logs. The method could be used to identify potential points of failure in an intact dam or levee structure.

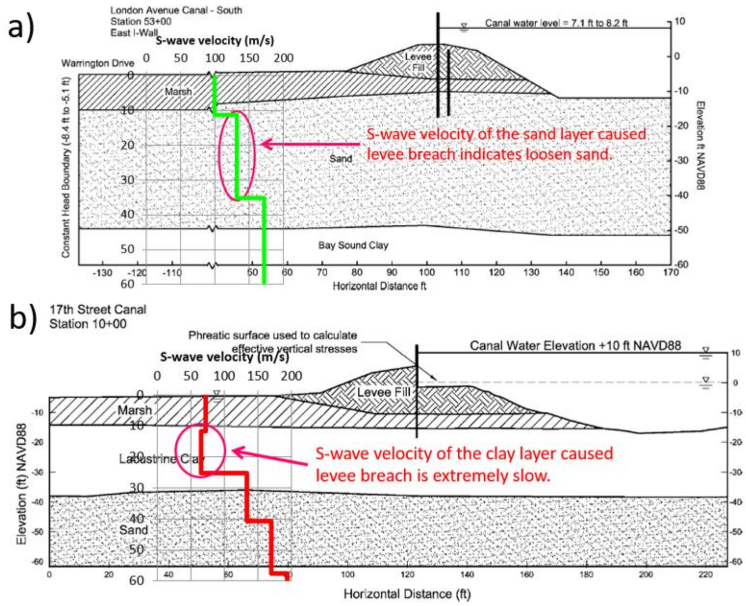

Figure 8: Comparison of soil profiles (Duncan et al., 2008) and S-wave velocity profiles at London Avenue Canal (a) and 17th Street Canal.

References

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