Seismic waveform changes associated with precipitation revealed by a geophone array and DAS

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Introduction

To evaluate the temporal change in the infrastructures such as roads, embankments, highways, bridges, crude oil storage, wastewater storages, and dams, we have applied the time-lapse method. In road and/or embankment, the temporal change of physical properties affecting to the life of constructions can be seen by *V*p and/or *V*s of the ground layer. In the time-lapse study, we used a seismic vibrator and a geophone array and the optical fiber DAS (Distributed Acoustic Sensor).

Field test

The test was carried out in the field of main institute of the CRIEPI in Abiko city, Japan between afternoon of 21st and morning of 24th, September 2017. Three optical fibers for DAS were buried in 20 cm depth parallel to each other. We used Mini-Vib as a horizontal seismic source which vibrated in the direction of the elongation of the fibers and 4.5 Hz geophone array. We activated the Mini-Vib every half hour during the daytime and stacked the data. Vibration data obtained by fibers were processed by DAS technology (Hartog *et al.*, 2013, Hartog, 2017). In this experiment, we used Schlumberger hDVS. The geology of the test field comprises loam layer (clay and silt) according to boring data. There is a layer boundary of the soft sediment (N=10) and the denser layer (N=30~40) at 8 m depth.

Result

Between 23:00 in September 22 and 09:00 in September 23, 22 mm precipitation was observed. The DAS time-lapse data obtained by one optical fiber gave good seismic records. The temporal change between two DAS dataset is subtle. In the DAS records, distinction of P, S and surface waves are not clear due to smaller P amplitudes than vertical geophone. To examine precipitation, influence for P, S and Rayleigh waves, we used 4.5 Hz vertical geophone records. The comparison of two geophone dataset before the rain shows extremely small difference. The comparison of two geophone dataset after the rain gives the similar results as one before the rain. However, the precipitation effect is large if we compare ones before and after the rain. This temporal change due to precipitation is evidently seen. We obtain the travel time change of each arrival time by the difference of instantaneous phase calculated by the Hilbert transform of each waveform. The influence of precipitation is large for the Raleigh-wave part. The largest travel time change is ~15 ms for 50 to 150 m offset distance. The velocity of Rayleigh wave for the surface layer is roughly 100 m/s because the travel time from the source to the nearest geophone is 0.5 seconds. The time delay is 15 ms / 0.5 seconds corresponding to 3% slower. On the other hand, the changes of P or S waves are only a few milliseconds at most.

Discussion and Conclusions

The influence of 22 mm precipitation is up to 15 ms travel time delay corresponding to 3% Rayleigh velocity change. However, the change in the travel time of body wave part is quite small, roughly few milliseconds. The reason of this discrepancy seems that the Rayleigh wave travels in the uppermost layer, and body waves mainly travel in the second layer below the top soft sediment. When we treat the time lapse, we should consider the precipitation effects on surface waves and the travel path variation.

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