Evaluation of fiber optic DAS as a dense seismic array for continuous monitoring of civil engineering structures

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Introduction

In the civil engineering, the early detection of damaged locations and regular maintenance for roads, embankments, highway and bridges are one of the costly and headache matters by the management authorities. Because the above structures have characters of long distances, if we use some sensors to detect any unusual changes in structures, huge number of high sensitivity sensors are needed. Recently, the fiber optic DAS (Distributed Acoustic Sensor) technology has been used in oil and gas exploration as new seismic sensors. It behaves like seismometer array but gives extremely dense dataset at a few m intervals along the optical fiber elongation. The DAS uses backscattering of input laser light at any locations, and it might measure seismically induced strains at any locations. If the sensitivity of DAS is high enough to detect unusual signals associated with fractures or shear wave velocity decrease suggesting weakening of soils, we might use the DAS for civil engineering purpose. To evaluate the sensitivity and the characteristics of DAS for seismic waves, we carried out a field test.

Field study

We used three 100-m-long fiber optic cables buried at 20 cm depth below the ground. Three kinds of geophones were used for comparison. The one hundred 4.5 Hz vertical geophones were placed near the fibers with 1 m spacing. In addition, 18 3C low frequency seismometers were also used. As seismic sources, we used hammer shots and MiniVib. The test was carried out during September 21 and 24, 2017 at the CRIEPI site. The upper 8 m of the ground is soft with N˜10, and lower than 8 m is consolidated layer with N=30˜40. The hammer shot at every 5 m was done to obtain surface wave dispersion curves (Yamauchi *et al.*, 2018). A MiniVib was operated at every half hour during the daytime with the sweep range of 10-100Hz during 20 second. To evaluate S/N and sensitivity, we directly compared DAS data and vertical geophone data although two devices provide different physical quantity and sensitivity directions. DAS data were average strain rate over 5 m distance though we obtain 1 m spacing data. On the other hand, a vertical geophone gives vertical particle velocity of the ground. The sensitivity of 4.5 Hz geophone is 350 V/m/s.

Results

We recorded hammer shots and MiniVib vibrations by all sensors. The comparison of DAS and geophones showed similar but slight different interpretation for observed data. DAS detect P, S and surface waves, but surface waves are a little ambiguous due to 5 m averaging. The S/N of DAS seems as nearly comparable to geophones for P and S arrivals. The three fibers provide similar waveforms. However, amplitudes of microtremors are slightly different among three fibers.

Discussion and Conclusions

Through the evaluation test, we obtained reasonable sensitivity of vibration along the elongation of fibers. We evaluated waveforms in the same physical domain as seismometers and extremely nice agreement between seismometers and DAS (Hasada *et al.*, 2018). DAS can give vibration data at every a few meters along 20-40 km distance in real-time. If we use this DAS technology for the continuous monitoring of road or embankments, we can provide information on early warning during heavy rains, flooding or instantaneous landslides.

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