Comparison of the records by optical fiber DAS (Distributed Acoustic Sensor) and geophone using natural earthquakes

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Introduction

In the civil engineering field, the maintenance of infrastructures such as roads, embankments, highways, bridges, crude oils storage, wastewater storage, and dams are one of the most important matters. Because the above structures have characters of long distances, if we use seismometers for seismic monitoring of the change in the structures, huge number of seismometers are needed. DAS (Distributed Acoustic Sensor) technology can give seismic records at a few meters interval along the optical fiber elongation. Because DAS uses backscattering of input laser light at any locations, it might sense the strain at the target location. There are wide applications of DAS (*e.g.* Hartog *et al.*, 2013). On the other hand, ordinary magnet-coil geophone measures the particle velocity, or displacement rate. This suggests two measurements are not the same. To examine this discrepancy of measurements quantitatively, we carried out a field test using the Schlumberger hDVS system and geophones.

Field study

We used three 100-m-long optical fibers buried at 20 cm depth below the ground surface. Three different kinds of geophones were used for comparison. The one hundred 4.5 Hz vertical geophones were placed near the fibers at 1 m spacing. In addition, ten 1 Hz 3C geophones and eight 0.2 Hz 3C geophones were placed along the fibers with 10–20 m spacing. According to Schlumberger Co., the hDVS measures the strain rate (Hartog, 2017). To compare the geophone records and DAS records, we calculated stain rates using the geophone waveforms. If we calculate the difference between horizontal waveforms to the direction of the fibers recorded at two stations and divide by the distance, it could be the normal strain rate. To eliminate the site effects on the waveforms, we used the averaged strain rate calculated by all nearest pairs of 3C geophones. We observed two natural earthquakes (M3.1 at Ibaraki and M4.2 near Izu Oshima) during the test study, and the both epicentral distances were approximately 100 km from the test site.

Results

From the DAS waveforms for M3.1 Ibaraki earthquake, it should be noticed that these are array seismic records within 100 m distance despite they are not ordinary ones of seismic reflection survey. Three fibers located approximately the same positions show nearly the same waveforms although some subtle differences are seen. Based on the comparison of the calculated strain rate using geophones and the DAS records for M3.1 Ibaraki earthquake, it is surprising that two waveforms show almost identical ones although amplitude variations show some difference. For another M4.2 earthquake which occurred near Izu Oshima, we obtained similar waveform resemblance.

Discussion and Conclusions

We examined the physical meaning of DAS measurements and the comparison of DAS and geophone waveforms in strain rate domain gave extremely nice fitting among two. However, geophones were placed on the ground and fibers were buried in the ground, so that each sensor can be affected by the local ground condition of the site in a different way. Among the waveforms obtained by three fibers, we recognize some differences, while the discrepancy among two geophones at the same location is smaller than ones by DAS. This could be due to variation of the sensitivity and/or coupling to ground. For the measurements in the borehole or at the ocean floor, we might consider to get the same coupling to the ground.

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