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Installation of borehole seismometer for earthquake characteristics in deep geological environment

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1. Introduction

Deep geological disposal is currently accepted as the most appropriate method for permanently removing spent nuclear fuel from the living sphere of humans. For implementation of deep geological disposal, we need to understand the geological changes that have taken place over the past 100,000 years, encompassing active faults, volcanic activity, elevation, subsidence, which as yet have not been considered in assessing the site characteristics for general facilities, as well as to investigate and analyze the geological structures, fracture systems and seismic responses regarding deep geological environment about 500 meters or more underground.

In regions with high seismic activity, such as Japan, the Western United States and Taiwan, borehole seismometers installed deep underground are used to monitor seismic activity during the course of seismic wave propagation at various depths and to study the stress changes due to earthquakes and analyze the connection to fault movements.

Korea Hydro & Nuclear Power Co., Ltd. (KHNP) have installed the deep borehole earthquake observatory at depths of about 300 to 600 meters in order to study the seismic response characteristics in deep geological environment on June, 2014 in Andong area. This paper will show the status of deep borehole earthquake observatory and the results of background noise response characteristics of these deep borehole seismic data as a basic data analysis.

2. Installation of deep borehole earthquake observatory

KHNP have installed borehole seismometer (Guralp CMG3TB5TB) at depths of 300 m (station ID : ADD1) and 600 m (station ID : ADD2) as shown in Fig. 1. Each borehole seismometer comprises a broadband seismometer and an accelerometer which has adopted a 24bit Analog to Digital board. The broadband seismometer is installed to focuses on micro earthquakes. The accelerometer enables ground acceleration of any size to be measured in case that strong ground motions causes the seismometer to go beyond its capacity so that it fails to measure correctly. Fig. 2 shows the major procedure of deep borehole seismometer installation.

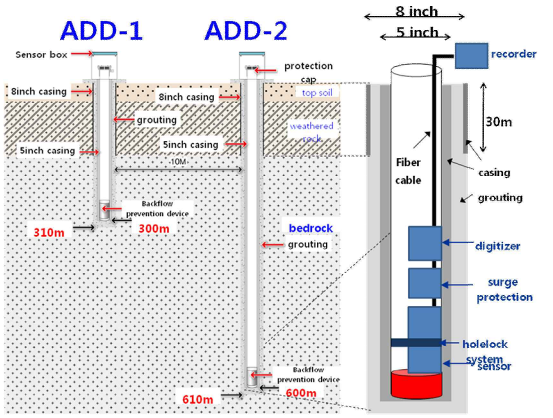

Fig. 1. The schematic diagram of deep borehole seismometer installation .

Once boring is completed, the sensor will be installed. The followings are major procedure of borehole seismometer installation as shown in Fig. 2.

- drilling and excavation of deep borehole
- cable routing and ground connection
- test of all equipments (sensor, recorder etc)
- check hole lock and strain relief in hole
- sensor installation to borehole
- check orientation and basic data analysis
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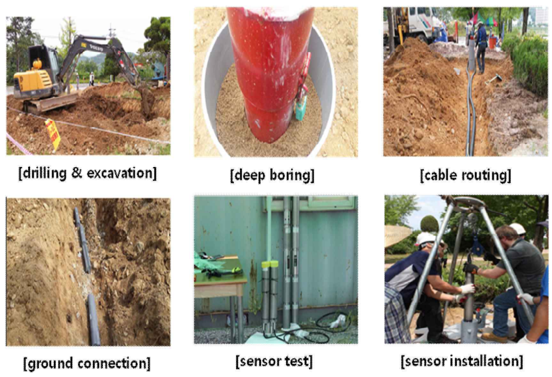

Fig. 2. An overview of the deep borehole seismometer installation procedure.

3. Data processing

3.1 Orientation of the seismometer

The installation of a sensor in a deep borehole does not permit its orientation, so that they have to be inferred indirectly [1]. We use different methods to determine the orientation of the borehole seismometer.

As a first step, we apply a cross-correlation analysis to a window of 300s of background noise waves, recorded by the sensor at the surface and at each depth. Then we rotate the borehole horizontal components at steps of one degree and calculate the cross-correlation between borehole components and surface horizontal recordings, NS and EW oriented. Repeating this procedure the highest value of cross-correlation is fount for -127 degree for ADD1 and -122 degree for ADD2.

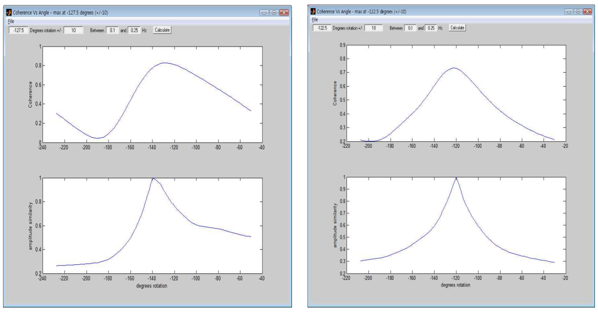

Fig. 3. Orientation results of (a) ADD 1 (-300 m) and (b) ADD 2 (-600 m) using background noise record both by the borehole and surface broadband sensor.

3.2 Probability Density Function of background noise

The background noise analysis method presented in McNamara & Buland (2004) allows one to analyze the background noise level by using the data collected without removing or differentiating waveforms caused by earthquakes or data damages due to momentary mechanical malfunctions [2]. Since most seismic observation data contain background noise, the density is probabilistically high; and because false signals due to signal or instrument errors during an earthquake are generally temporary, the frequency is probabilistically low. If a Probability Density Function (PDF) based on such statistical characteristics is used in background noise analysis, the characteristics of the major background noise recorded at a seismometer can be determined, and it is useful in the analysis or automated analysis of data collected over a long period.

Fig. 4 and Fig. 5 show the (PSD) of background noise resulting from the ADD 1 and ADD 2. As these figures show, the background noise characteristics depending on frequency were very low.

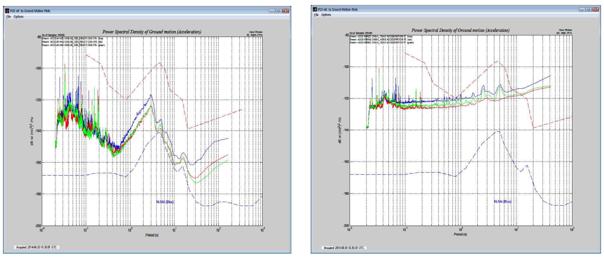

Fig. 4. Probability Density Function (PDF) of background noise which are recorded by (a) Broadband seismometer (b) accelerometer of ADD 1

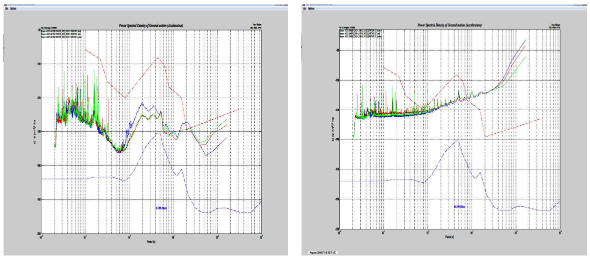

Fig. 5. Probability Density Function (PDF) of background noise which are recorded by (a) Broadband seismometer (b) accelerometer of ADD 2

4. Conclusion and Discussion

We present here the status of deep borehole seismometer installation by KHNP. In order to basic data analysis for the borehole seismic observation data, this study shows the results of the orientation of seismometer and background noise characteristics by using a probability density function. Together with the ground motion data recorded by the borehole seismometers can be utilized as basic data for seismic response characteristics studies with regard to spent nuclear fuel disposal depth and as the input data for seismic hazard assessment that distinguishes response by depth.

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[2] D. E. McNamara and R. P. Buland, Ambient noise levels in the continental united states, Bulletin of Seismological Society of Americal, Vol, 94 No.4, pp.1517-1527, 2004.

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