Transactions of the Korean Nuclear Society Autumn Meeting
Gyeongju, Korea, October 26-27, 2023

Strong Ground Motion Simulations at UCN Seismic Station Considering 2023 & 2019 Donghae Events

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***Keywords:** strong ground motion simulation, 2023 & 2019 Donghae events, empirical Green's function

1. Introduction

An earthquake of M_L 4.5 occurred at the offshore Donghae on 15 May 2023 (hereafter, 2023 Donghae event). The maximum seismic intensity of this event was III in Gangwon and Gyeongbuk areas, and II in Chungbuk area. It did not affect the safety of the Hanul nuclear power plant (NPP) site which is about 90 km away from the epicenter. Meanwhile, there had been an earthquake of M_L 4.3 near the epicenter on 19 April 2019 (hereafter, 2019 Donghae event). Considering hypocenters, similarities of seismic waves recorded at common seismic stations and similarities of fault plane solutions of two events, these events might occur at the same fault.

In this study, strong ground motions at UCN seismic station by a scenario earthquake (M_W 6.0) on the causative fault of 2023 & 2019 Donghae events are simulated by using an empirical Green's function (EGF) method, and are indirectly compared with the standard design response spectrum of RG 1.60 [1] (anchored to 0.2 g) at the site. UCN seismic station has been operated by the Korea Institute of Nuclear Safety (KINS) since 1999 and is located within Hanul NPP site.

2. Methods and Results

2.1 Source Parameters

The Korea Meteorological Administration (KMA) reported that the hypocenters of 2023 & 2019 Donghae events are (37.87°N, 129.52°E, 31 km) and (37.88°N, 129.54°E, 32 km), respectively [2]. However, considering focal depths of inland earthquakes, their focal depths are judged to be too deep, and there are likely to include considerable uncertainty. Meanwhile, the Korea Institute of Geoscience and Mineral Resources (KIGAM) estimated the focal depths of two events to be 17.5 km [3]. The fault plane solutions and magnitudes of two events are summarized in Table 1.

Table 1. Fault plane solutions and magnitudes of the events

	KMA [2] (strike, dip, rake), M_W	KIGAM [3] (strike, dip, rake), M_W
2023	(179°,44°,96° or 350°,46°,84°), 3.73	(162°,93°,40° or 338°,50°,88°), 3.75
2019	(173°,44°,96° or 345°,46°,84°), 3.89	(174°,40°,102° or 339°,51°,80°), 3.89

Two events show typical reverse faulting, and the directions of P-axis are ENE-WSW (Fig. 1). The direction is similar with the main stress direction in the Korean Peninsula. Considering the distribution of aftershocks, the directions of strike and dip of the causative fault are expected to be NNS-SSE and WSW, respectively [3].

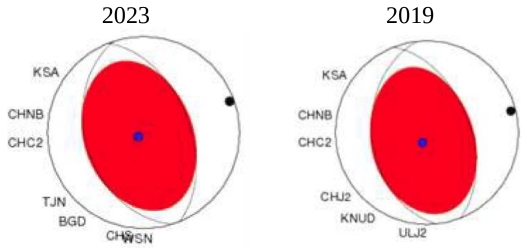

Fig. 1. Fault plane solutions of the events [3]

2.2 Empirical Green's Function Method

If two different earthquakes that occurred at the same fault were recorded at the same seismic station, they would eventually share path and site characteristics. Therefore, if a relative adjustment of their seismic sources is well conducted, observed ground motions of an earthquake (element event) can be used as a Green's function for a larger earthquake (target event) that occurred on the same fault. As such, the observed ground motions that can be used as a Green's function is called the empirical Green's function (EGF) and the EGFM code is used for strong ground motion simulations by the EGF method [4]. For events larger than M_W 5.0, the scaled energy is almost constant and it means that they obey self-similar scaling [5], but it is still under debate. C factor is used to correct the difference in stress drop between element and target events [4]. Here, C factor was derived from 2016 Gyeongju earthquake sequences [6].

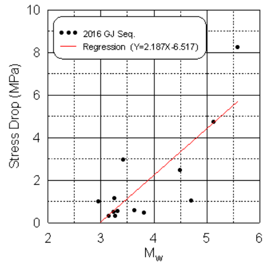

Fig. 2. C factor derived from 2016 Gyeongju earthquake sequences

Table 2 shows the input parameters for simulating strong ground motions at UCN seismic station considering 2023 & 2019 Donghae events.

Table 2. Input parameters for EGF method (l, w: subfault length and width, N_{cal}, N : calculated and adjusted length ratio of target fault and subfault, C: C factor, $|\Delta M_W|$: absolute difference between moment magnitudes of the target event when N is used instead of N_{cal}, V_S: shear wave velocity)

	l	w	N_{cal}	N	C	$\|\Delta M_W\|$	V_S
2023	0.5	0.5	8.46	8	3.922	0.05	3.5
2019	0.5	0.5	7.61	8	3.318	0.04	3.5

Simulated ground motions of the target event (M_W 6.0) by assuming that ground motions by 2023 & 2019 Donghae events are EGFs, with east-west and north-south components are presented in Fig. 3.

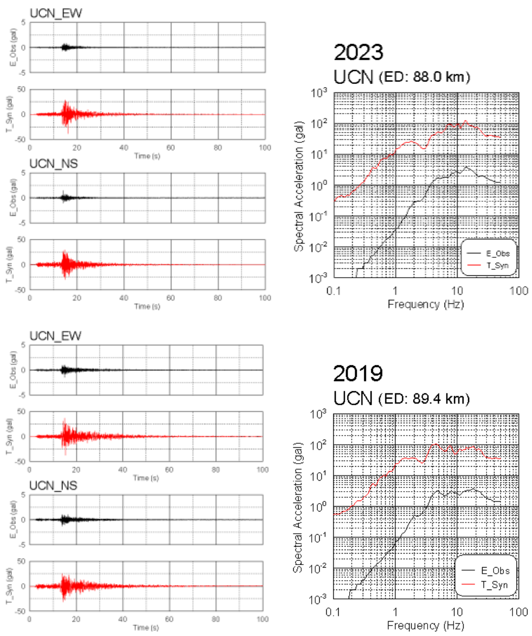

Fig. 3. Observed (black solid line) and simulated (red solid line) waveforms and response spectra for 2023 (upper) & 2019 (lower) Donghae events. The Response spectra are given as the geometric mean of two horizontal components (EW: east-west, NS: north-south, ED: epicentral distance).

2.3 Comparison with Design Response Spectra and Ground Motion Model

Fig. 4(a) shows horizontal standard design response spectra of RG 1.60 [1] (anchored to 0.2 g). Simulated response spectra at UCN seismic station by the EGF methods are found to be considerably below RG 1.60 response spectra, but a lot of attention in interpretation is required since the assumed input data was used. Fig. 4(b) shows the results of comparing peak ground acceleration (PGA) by a ground motion model (GMM) of KEPRI [7] with that of simulated ground motions by the EGF method. At a distance of about 90 km, PGA by the EGF method is slightly larger than that by GMM of KEPRI [7].

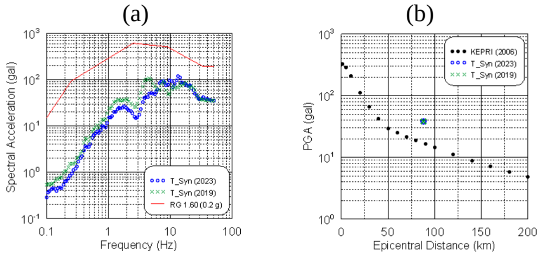

Fig. 4. (a) Simulated response spectra by 2023 (blue dotted line) and 2019 (green dotted line). Horizontal standard design response spectrum of RG 1.60 [1] anchored to 0.2 g is also depicted in red solid line. (b) Comparison between PGAs by the EGF method and by GMM of KEPRI [7]

3. Conclusions

The EGF method is applied to simulate strong ground motions at UCN seismic stations within Hanul nuclear power plant site by an assumed large target event with M_W 6.0 on the causative fault of 2023 & 2019 Donghae events with M_W 3.75 & 3.89. Simulated response spectra have been found to be considerably below standard design response spectra anchored at 0.2 g, and it is not expected to affect the safety of the Hanul NPP site. However, a lot of attention in interpretation is required since the assumed input data was used.

Acknowledgement

This work was supported by the Korea Foundation of Nuclear Safety using financial resources granted by the Nuclear Safety and Security Commission (No. 2205001).

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