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# Preliminary seismic safety evaluation of the Uljin nuclear power plant site regarding the offshore Uljin earthquake on the 29 May 2004 as an empirical Green's function

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## 1. Introduction

The moderate earthquake of magnitude 5.2 was occurred at the offshore Uljin on the 29 May 2004. The magnitude of the event is the largest one which is equal to that of the Sokrisan earthquake on the 16 September 1978 since the beginning of the instrumental recording by the Korean Metrological Administration (KMA) in 1978. The magnitude of the event was large enough to be felt in a wide area of the southern Korea. It did not affect the safety of the Uljin nuclear power plant (NPP) site which is about 80 km away from the epicenter.

In this article, we estimate source parameters of the event and evaluate preliminary seismic safety of the Uljin NPP site regarding the event as an empirical Green's function (EGF).

## 2. Source Parameters

### *2.1 Epicenter Location*

After gathering seismic data from seismic network operation bodies in Korea, such as the KMA and the Korea Institute of Geoscience and Mineral Resources (KIGAM), the first arrival times of P waves are selected. Locations are calculated by making use of HYPOINVERSE-2000 [1] with the 1D crustal velocity model [2] and its modified model reducing crustal thickness by 5 km considering the transition from continental crust to oceanic crust in the East Sea [3]. The epicenter was relocated to be 36.6877°N and 130.1341°E for the 1D crustal velocity model. The epicenter for the modified model was little changed.

### *2.2 Focal Mechanisms*

With the relocated epicenter, the focal mechanism of the event was estimated by the waveform modeling. Both the crustal velocity model [2] and its modified model were also adopted for the waveform inversion analysis with a $V_P/V_S$ ratio of 1.78. The crustal $Q_S$ of 380 was used based on [4], but it has little effect on the long period waveform modeling. We removed the instrumental responses from the broadband seismic data, and applied a bandpass filter of 0.02 to 0.05 Hz.

We excluded the isotropic components of the moment tensor and considered only the deviatoric components to express the earthquake by faulting. We allowed a relative time shift of seismic traces in the waveform inversion analysis. We performed the waveform inversion analysis using ISOLA software [5].

For the crustal velocity model [2], the seismic moment is estimated to be $3.4\times10^{16}$ N·m which corresponds to the moment magnitude 5.0. We determined the focal depth of the event as 9 km. Two fault planes were obtained from the waveform inversion analysis. One is 354° in strike, 46° in dip and 89° in rake, and the other is 175° in strike, 43° in dip and 91° in rake. The seismic moment, focal depth and two fault plane solutions for the modified model were not different from those for the crustal velocity model [2].

The event shows typical thrust faulting, and the direction of P-axis (84°) is nearly E-W. The direction is similar with the main stress direction in the Korean Peninsula and its surrounding areas [6].

### *2.3 Spectral Analysis*

Fourier amplitude spectra were calculated by the composite spectrum method by [7] which vectorially combines 3 components in the frequency domain. We applied [4] for the attenuation term. Local site effects of observatories were not considered because of insufficient information. Seismic data from eighteen broadband stations were selected for the spectral analysis of the mainshock. The grid search method [8] was applied to estimate the moment magnitude, corner frequency and stress drop. The estimated moment magnitude, corner frequency, and stress drop of the mainshock are 4.9±0.1, 1.3±0.3 Hz, and 10.5±5.3 MPa, respectively. The moment magnitude is very similar to that by the waveform inversion analysis. The stress drop of the event is very similar to average stress drop (10 MPa) accompanied by intraplate earthquakes.

### *2.4 Regional Stress Field Inversion*

To assess the state of stress around the epicenter, the P- and T-axis of the focal mechanisms of the event and eight other earthquakes are inverted for the local stress tensor. Most earthquakes are concentrated around the basement escarpment along the western and southern slopes of the Ulleung basin. Using the computer program FMSI [9], we determined the best fitting regional stress tensor by inverting nine earthquakes.

The result of the stress inversion indicates that σ1 trends 275° with a plunge of 0°, whereas σ3 trends 184° with a plunge of 42°. It appears that the E-W trending

P-axis for the 29 May 2004 event represents a persistent trend in the basement escarpment.

## 3. Empirical Green's Function

One of the most effective methods for simulating strong ground motion that comes from a large earthquake is to use observed records from small earthquakes occurring around the source area of a large earthquake. Actual geological structure from source to site is generally more complex than that assumed in theoretical models. We simulated strong ground motion for a potential earthquake regarding the offshore Uljin earthquake as an EGF. We evaluate preliminary seismic safety of the Uljin NPP site by comparing design response spectrum (DRS) of the site with response spectrum of simulated strong ground motion by the potential event.

Table 1 shows input parameters for the basis and target event. The basis event is the offshore Uljin earthquake with magnitude 5.0, and target event is the potential earthquake with magnitude 6.5. The focal mechanisms of the target event are equal to those of the basis event. We obtained the fault area considering the empirical relationships between magnitude and rupture area [10], and simulated strong ground motion for the target event using the distributed program [11].

Figure 1 shows acceleration seismograms and response spectrums by the basis and target event whose fault plane solutions are 354° in strike, 46° in dip and 89° in rake. The response spectrum by the potential event with magnitude 6.5 is laid under the DRS of the site. The DRS of the site is made by scaling the value of zero period (0.2 g). There will be no severe effect on the seismic safety of the site although a potential event with 6.5 may occur around the basement escarpment.

Table I: Input parameters

| | |
|---|---|
| S wave velocity | 3.5 km/s$^2$ |
| rupture velocity | 2.7 km/s$^2$ |
| rise time | 0.2 s |
| number of subfault | 49 |
| stress drop ratio | 1.0 |
| fault area | 256 km/s$^2$ |

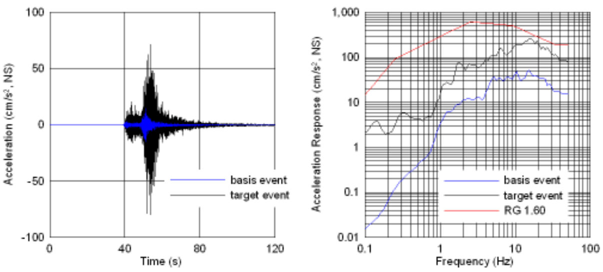


Fig. 1. Acceleration seismograms (left) and response spectrums (right) of the basis and target event. The DRS of the Uljin NPP site is also depicted.

## 4. Summary and Discussion

We estimated source parameters of the offshore Uljin on the 29 May 2004 and evaluated preliminary seismic safety of the Uljin NPP site regarding the offshore Uljin earthquake on the 29 May 2004 as the EGF. The potential earthquake with magnitude 6.5 may give no severe effect on the seismic safety of the Uljin NPP site considering the DRS of the site.

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