Estimation of Cumulative Absolute Velocity using Empirical Green's Function Method

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1. Introduction

In recognition of the needs to develop a new criterion for determining when the OBE (Operating Basis Earthquake) has been exceeded at nuclear power plants, Cumulative Absolute Velocity (CAV) was introduced by EPRI. The concept of CAV is the area accumulation with the values more than 0.025g occurred during every one second. The equation of the CAV is as follows.

$$CAV = \int_0^{t_{max}} |a(t)| dt \qquad (1)$$

t_{max} = duration of record
a(t) = acceleration (>0.025g)

Currently, the OBE exceedance criteria in Korea is Peak Ground Acceleration (PGA, PGA>0.1g). When Odesan earthquake (M_L=4.8, January 20th, 2007) and Gyeongju earthquake (M_L=3.4, June 2nd, 1999) were occurred, we have had already experiences of PGA greater than 0.1g that did not even cause any damage to the poorly-designed structures nearby. This moderate earthquake has motivated Korea to begin the use of the CAV for OBE exceedance criteria for NPPs. Because the present OBE level has proved itself to be a poor indicator for small-to-moderate earthquakes, for which the low OBE level can cause an inappropriate shut down the plant. A more serious possibility is that this scenario will become a reality at a very high level.

Empirical Green's Function method was a simulation technique which can estimate the CAV value and it is hereby introduced.

2. Methods and Results

2.1 Empirical Green's Function (EGF) Method

The techniques by which waveforms for large events are synthesized after the empirical Green's function method proposed by Hartzell [1]. We use the empirical Green's function method formulated by Irikura [2], based on a scaling law of fault parameters for large and small events and the omega-squared source spectra by Aki [3]. The waveform for a large (target) event is synthesized by summing the records of small events with correction of the difference in the slip velocity time function between the large and small events scaling laws.

The numerical equations to sum records of small events are

$$U(t) = \sum_{i=1}^{N} \sum_{j=1}^{N} \frac{r}{r_{ij}} F(t) * (C \cdot u(t)) \qquad (2)$$

Where U(t) is the simulated waveform for the large event, u(t) is the observed wave form for the small event, C is the ratio of stress drop between large and small event. F(t) is the filtering function.

2.2 Characteristics of Odaesan Earthquake

On January 20th, 2007, an earthquake of local magnitude 4.8 occurred near Mt. Odae (the earthquake was named concisely as the 'Odaesan earthquake').

Odaesan earthquake is one of the largest earthquakes which had occurred in inland of Korea. The source characteristics of Odaesan earthquake are shown in Table 1 and Fig. 1 [4, 5].

Table 1 : Characteristics of Odaesan earthquake

origin time	07/01/21, 20:56:53.6
epicenter	128.5841°E, 37.6889°N
focal depth	12 km
moment magnitude	4.6
stress drop	137 bar
moment tensor solution	296/85/0, 26/90/-175

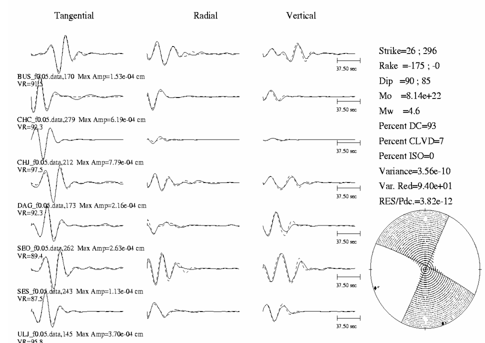

Fig. 1. Moment tensor solution of Odaesan earthquake

2.3 Parameter Estimation for Simulation.

To simulate the target (large) earthquake (Mw=5.6), the records at the DGY station about 7.9 km from epicenter of Odaesan earthquake was selected by Green's function (subfault event). The parameter for simulation is described in Table 2 [6, 7, 8]. In this simulation we calculated 4 different fault geometries (Table 3) to consider more reliable earthquake dimension.

Table 2 : Parameter study for simulation

S wave velocity	3.5 km/sec^2
rupture velocity	2.7 km/sec^2
rise time of subfualt	0.1s
N (number of subfault)	9
C (stress drop ratio)	1.24
epicentral distance	7.9 km
azimuth	88.2
fault area (target fault)	48 km/sec^2

Table 3 : Case study for target earthquake simulation

	Case I	Case II	Case III	Case IV
strike	296	26	296	26
dip	85	90	85	90
rake	0	-175	0	-175
W	2.3 km	2.3 km	3.3 km	3.3 km
L	2.3 km	2.3 km	1.8 km	1.8 km

2.4 results

An example of simulated waveform and estimated CAV value is shown in Fig. 2.

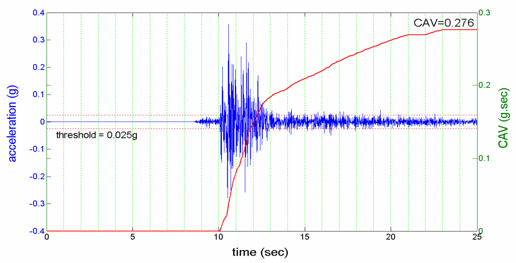

Fig. 2. Example of simulated waveform

The value from random vibration simulation result (0.13g) showed comparatively lower OBE exceedance criteria than that of the present result. As seen in Figures 3 and 4, the CAV value of using EGF method which is used real observation data (Odaesan earthquake data) for Green's function, the simulation results are larger than the value produced from the previous simulation method [9].

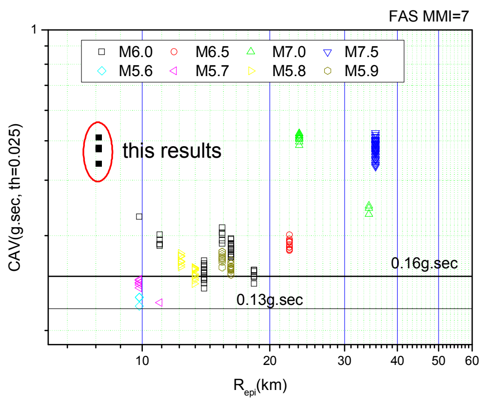

Fig. 3. Estimated CAV value in FAS-MMI VII

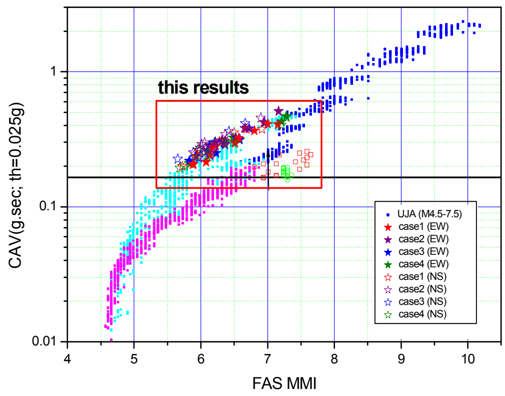

Fig. 4. Relation between the CAV value and the instrumental MMI Intensity (FAS MMI)

3. Conclusions

The present study on OBE exceedance criteria using EGF simulation technique showed larger CAV value than the previous simulation technique.

As far as EGF simulation method uses real data, more reliable new OBE exceedance criteria with CAV value can be developed using observed intermediate earthquake data in the Korean Peninsula as Green's function.

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