Estimation of Paleoearthquake Magnitude : Deterministic Method

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1. Introduction

The nuclear facilities require to withstand an effect of the earthquake that may occur during their lifetime. However, it is not easy to predict accurately the potential of earthquake that may occur in their sites. It has been debated that some of the Quaternary faults near the nuclear power plant site in SE Korean peninsula are active or not since early 1990's. In case that those are the active fault, estimating the size of earthquakes from the fault is one of the most important issues in the seismic hazard analysis for nuclear power plants. In this study, we discussed the methods for evaluation of the maximum potential earthquake, and estimated the size of paleoearthquake from the fault sources.

2. Methods and Results

Estimating the size of earthquakes that can occur along a fault or within a given region is a fundamental element of any analysis of seismic hazards. To estimate the maximum potential earthquake, the geological parameters such as rupture length, rupture area, displacement, slip rate, and recurrence interval should be investigated, and in particular, fault rupture length, displacement, slip rate are the most important. Estimating earthquake size, however, is not simple, and many approaches and methods have been studied in the last few decades[1,2]. In this study, five methods were carried out to scale earthquake size, which are the fault rupture length, rupture area, fault displacement, seismic moment and moment release rate methods. It was calculated the size of maximum credible earthquake from the fault sources considering the features of the Quaternary faults.

2.1 Surface Rupture Length Method

It has made many efforts to derive the empirical equations of rupture length-earthquake magnitude from the statistical data of the seismogenic fault length and earthquake magnitude. We tried to estimate the paleo-magnitude through the empirical equations and fault lengths measured in the field. In case that the fault length is 1.5km based on field data, the range of magnitude shows M 3.70~6.44[3]. Moreover, there is a considerable difference of paleoearthquake magnitude by each equation. If the equations derived from local data were excluded, however, the results would be evenly distributed and the average value shows M 5.36 (Fig. 1). The surface fault length applied in the calculation may not indicate the surface rupture length occurred from one paleoseismic event but mostly the total fault length observed at the site. Therefore, maximum magnitude could have been over-estimated. On the other hand, if the surface faults were developed in the form of an en-echelon arrangement or over-stepping, the magnitude could be under-estimated. Because the actual fault length could be measured to be shorter than the estimated surface rupture length.

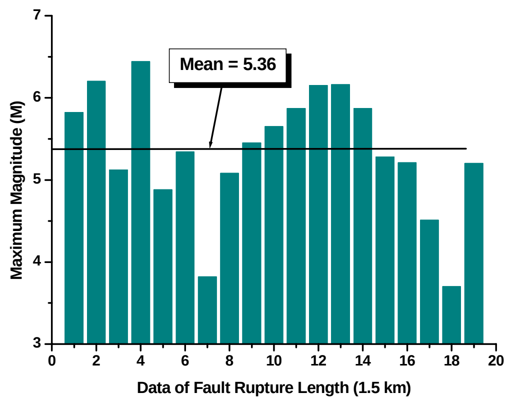

Figure 1. Distribution of paleoearthquake magnitude obtained from 19 different relationships between fault rupture length and earthquake magnitude.

2.2 Fault Displacement Method

From the empirical equations of maximum displacement-magnitude, we tried to estimate the paleo-earthquake magnitude that could reflect displacements observed in some faults. In case that the maximum displacement of the fault is 1.5m, the maximum magnitude shows M 6.82 to M 7.21(average M 6.98) and these show the more even distribution than those using the surface rupture length method (Fig. 2).

The method using fault displacement also has a limitation of input data. The relationships between fault displacement and earthquake magnitude usually apply the maximum displacement. In paleoseismological studies, the trenches which is excavated along a fault are more likely to represent an average displacement than a maximum displacement[2]. Thus, earthquake magnitude calculated in this study could have been under-estimated. On the other hand, paleoearthquake magnitude in multiple deformation can be over-estimated. To estimate the maximum earthquake potential, therefore, the movement history of Quaternary faults should be properly understood through the paleoseismological investigation such as trench survey.

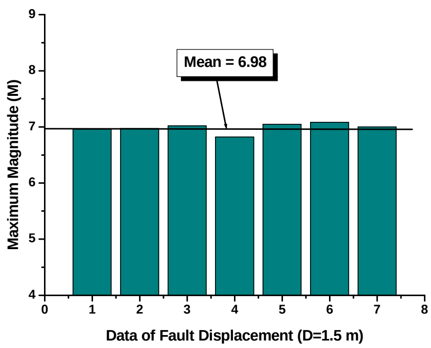

Figure 2. Distribution of paleoearthquake magnitude obtained from 7 different empirical relationships between maximum displacement and earthquake magnitude.

2.3 Rupture Area Method

The rupture area method uses an empirical correlation between historic earthquake magnitude and rupture area. In the absence of surface rupture evidence, it may be difficult to decide if the entire fault plane area, or only a portion of it, ruptured in a paleoearthquake. Recent works indicate that the rupture area of the Quaternary fault is 19.5km^2 from the surface fault length(1.5km) and the focal depth(13km) at a site of SE Korean peninsula. Although this result do not explain logically the fault geometry, magnitude shows the range of M 4.04~5.54 and mean of M 5.34 from the magnitude-area relations.

2.4 Seismic Moment and Moment Release Rate Methods

The seismic moment method is the most physically robust method of paleomagnitude estimation. And, it was suggested that the rate of seismic moment release should be an important parameter in evaluating the seismic risk of a fault system[4].

We estimated paleoearthquake magnitude using the seismic moment and moment release rate methods considering the fault sources developed in SE Korean peninsula[4,5,6]. We could obtain magnitude of M 6.14~6.40 and M 5.12~5.23 at the Eupcheon and Suryum faults by using the seismic moment method, respectively (Table 1). In case of the 1.5km fault length, 4m displacement, 10km depth, and 3.5×10^{11} dyne/cm^2 shear modulus, the moment release rate shows 2.63×10^{20} dyne·cm/year. Moreover, supposing elapse time of the fault is 80,000years, the estimated maximum potential earthquake shows magnitude of M 6.46.

The uncertainty can exist due to the anisotropic and heterogeneous characteristics of geological material and phenomena, however, it is need to perform detailed geological survey such as trenching in order to get the suitable input fault parameters.

Table 1. Seismic moment and earthquake magnitude obtained from the Eupcheon and Suryum faults.

Equations	Shear Modulus (dyne/cm^2)	Eupcheon (L:1.5km, W:10km, D:4m)		Suryum (L:150m, W:10km, D:1.5m)	
		Mo	M	Mo	M
Mw = (Log Mo - 16.05)/1.5 (Hanks & Kanamori, 1979)	3.0×10^{11}	1.80×10^{25}	6.14	5.40×10^{23}	5.12
	3.5×10^{11}	2.11×10^{25}	6.18	6.35×10^{23}	5.17
Log Mo = 17.0 + 1.3 M (Wesnousky et al., 1982)	3.0×10^{11}	1.80×10^{25}	6.35	5.40×10^{23}	5.18
	3.5×10^{11}	2.11×10^{25}	6.40	6.35×10^{23}	5.23

3. Concluding Remarks

To estimate the size of paleoearthquake from the Quaternary faults in SE Korean peninsula we carried out the 5 methods. On the basis of the fault parameters we could obtain M 5.36, M 6.98, M 5.34, M 6.40 and 6.46 by using the surface rupture length, displacement, rupture area, seismic moment and moment release rate methods, respectively.

We think that these different results of paleo-magnitude attributed to the various factors of over- and under-estimation in evaluating the earthquake potential, and may not fully identify the detailed geometry and dynamics of fault system. To evaluate the adequate earthquake potential the characteristics of fault system through the paleoseismological study should be fully considered in analyzing the seismic hazards.

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