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Evaluation of the Contribution of Seismic Hazard to Nuclear Power Plant Sites Based on Earthquake Distance

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1. Introduction

The seismic design and seismic safety assessment of nuclear power plants (NPPs) fundamentally begin with determining the potential seismic loads that a given site may experience. Seismic hazard assessment is a comprehensive procedure to evaluate the level of intensity and spectrum shapes. It can be conducted using deterministic and probabilistic approaches.

Probabilistic Seismic Hazard Analysis (PSHA) requires various input data, including seismic source models, activity rates, and ground motion models. To appropriately account for uncertainties in these inputs, Senior Seismic Hazard Analysis Committee (SSHAC) of the U.S. NRC developed the guidelines for the PSHA [1]. The SSHAC levels range from 1 to 4, and the level of PSHA for domestic nuclear power plants is known to be between 2 and 3. Increasing the SSHAC level requires significant efforts in data collection and expert consensus-building.

Small Modular Reactors (SMRs) are known to have relatively safer than conventional large reactors due to improved design and smaller quantities of radioactive materials. However, requiring the same level of PSHA as existing nuclear power plants may undermine the economic feasibility of SMRs, which need to be constructed at various sites. Implementing a simplified seismic hazard assessment approach could enhance cost efficiency, particularly during the site selection phase before the detailed design and operational stages.

Recently, international organizations such as the International Atomic Energy Agency (IAEA) have shown interest in developing a more simplified seismic hazard assessment for SMRs [2]. One proposed approach is to reduce the site area considered in the assessment. To implement such an approach, it is necessary to first analyze the contribution of seismic hazards as a function of distance and ensure that a significant portion of the hazard contribution originates within a reasonable distance.

This study analyzed the contribution of seismic hazard by distance to evaluate the applicability of a simplified PSHA approach to domestic sites by reducing seismic source areas.

2. Probabilistic Seismic Hazard Analysis (PSHA)

The input data were obtained from the PSHA conducted for the Uljin Nuclear Power Plant site in 2013, led by the Korea Atomic Energy Research Institute (KAERI). Fig. 1 illustrates the area seismic source model utilized in this PSHA. A total of four expert teams derived the shapes and seismic activity rates of the area seismic sources, and equal weighting was assigned to each area source map. Three Ground motion model (GMM) were used, and a standard deviation of 0.6 was uniformly applied to the GMMs. Fig. 2 shows the derived seismic hazard curves, respectively, for Peak ground acceleration (PGA) and 1 Hz spectral acceleration (SA).

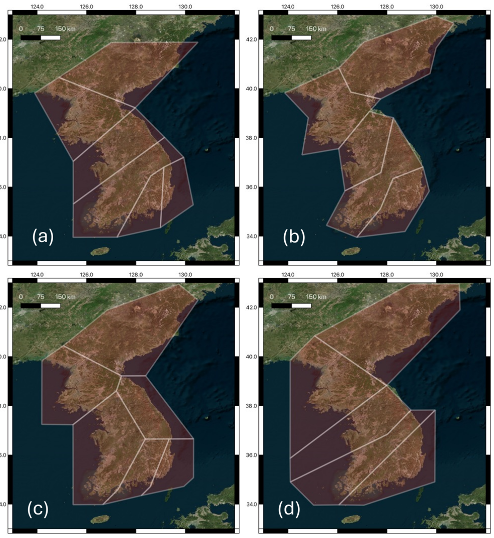

Fig. 1 Area Source Models for PSHA

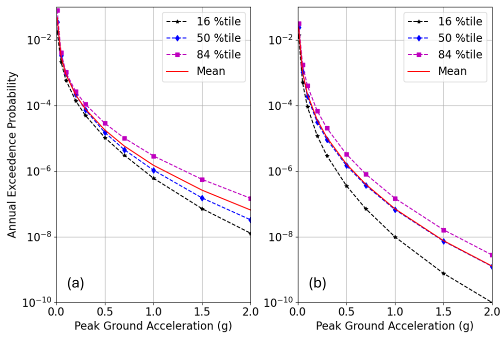

Fig. 2 Seismic hazard curves; (a) PGA (b) SA(1Hz)

3. Contribution of Seismic Hazard by Distance

A deaggregation analysis of PSHA results was conducted to evaluate the distance-dependent cumulative contribution of seismic hazard. Four acceleration levels of 0.2g, 0.3g, 0.5g, and 1.0g were determined for the deaggregation. Fig. 3 and 4 illustrate the contribution of seismic hazard by earthquake distance for PGA and SA (1Hz), respectively. The red horizontal line represents the point at which 90% of the total seismic hazard contribution is reached, and three green vertical lines indicate cut-off distances of 50 km, 100 km, and 200 km from the site, respectively.

Both the PGA and SA (1Hz) results show that over 90% of the seismic hazard contribution originates from earthquakes occurring within approximately a 50 km radius of the site. This finding suggests an accurate representation of seismic sources within this 50 km range could provide a reasonable approximation of the overall site-specific seismic hazard. This result is consistent across different acceleration levels, indicating that seismic events within this proximity dominantly influence hazard levels at the site.

However, further study is necessary regarding the completeness of the earthquake catalog within a 50 km radius, the methodology for estimating seismic sources and activity rates, and the consideration of fault seismic sources.

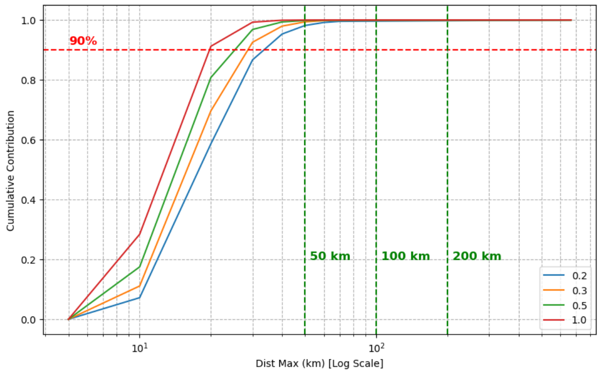

Fig. 3 Contribution of seismic hazard by earthquake distance (PGA)

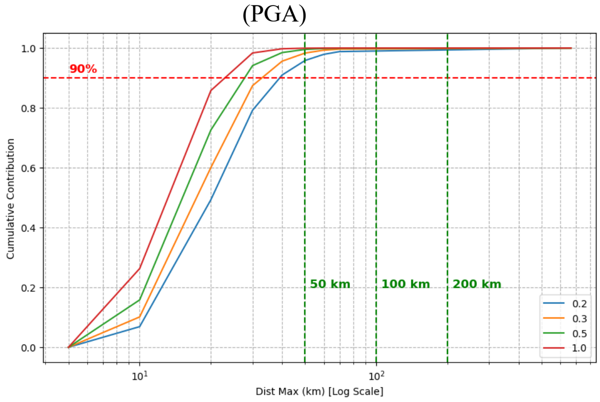

Fig. 4 Contribution of seismic hazard by earthquake distance (SA, 1Hz)

4. Conclusion

This study analyzed the distance-dependent contribution of seismic hazard at a domestic site using PSHA deaggregation. Results indicate that over 90% of the seismic hazard is derived from within a 50 km radius. This indicates that a small seismic source radius can be effectively used to simplify site-specific seismic hazard assessment without compromising accuracy, although this finding requires further study.

Acknowledgement

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