A Study on Relationship between Methodologies using Evaluating Seismic Performance of Structures

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1. Introduction

In case of nuclear power plants, seismic performances of them have been evaluated by either Seismic Probabilistic Risk Assessment (SPRA) or Seismic Margin Assessment (SMA) for an Individual Plant Examination for seismic events (seismic IPE). SPRA is based on the probabilistic methodology and SMA is based on the deterministic methodology. Seismic fragility analysis with 95% confidence value on 5% probability failure is used for SPRA and Conservative Deterministic Failure Margin (CDFM) approach with more than 84% confidence value on 5% probability failure is used for SMA. Both methodologies represent seismic performance of components as HCLPF (High Confidence Low Probability of Failure) capacities. In this study, by evaluating the seismic performances of the same structures by these two methodologies respectively, the relationship between them can be shown quantitatively.

2. Methodologies and Results

2.1 Methodologies

SPRA consists of seismic hazard analysis, seismic fragility analysis and system & accident-sequence analysis. Core damage frequency of nuclear power plant induced by seismic event can be present by these analyses. For use in SPRA, seismic performance of component is determined by seismic fragility analysis as a HCLPF capacity defined as ground acceleration capacity with 95% confidence value on 5% probability failure. In seismic fragility analysis, 50% median and 5% & 95% confidence curves of all components are presented respectively. For developing these curves median ground acceleration (A_M), randomness (β_R) and uncertainty (β_U) values are needed for dominant failure mode of a component and these values are able to be developed by detailed analyses using enough design information.

For SMA, after a Review Level Earthquake (RLE) defined as the earthquake level for which capacity with high confidence is to be demonstrated is selected, seismic HCLPF capacities of components which have capacities less than the specified RLE are calculated by CDFM approach. The HCLPF determined by this approach means ground acceleration capacity with more than 84% confidence value on 5% probability failure. The CDFM approach is that a RLE is conservatively defined first and the calculation of structural and equipment response to the conservatively defined earthquake is determined with no deliberate conservative bias. The assessment of capacity for the calculated response is performed conservatively by using approximately 95 percentile exceedance material strength, approximately 84 percentile strength prediction equations and incorporating conservative effects of structural system ductility.

2.2 Result

Generally the Korean nuclear power plants consist of six major buildings ranked by seismic category 1 such as Containment Building, Auxiliary Building, Fuel Building, CCW H/Ex Building, EDG Building, and ESW Pump House. Six seismic category I structures existing in nuclear power plants are selected as components to apply both methodologies. HCLPFs are obtained by seismic fragility and CDFM respectively and these HCLPFs are compared. As the results of studies the relationship between these two HCLPFs by probabilistic methodology using seismic fragility analysis and by deterministic methodology using CDFM approach are derived by **1.430 to 1.549**.

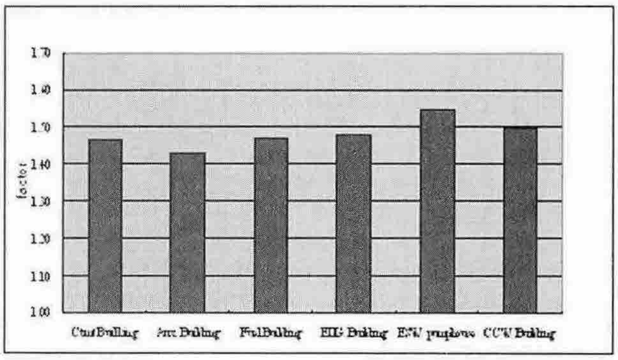

Figure 1. Factors for Each Structure by Two Methodologies

3. Validity

The relationship between the two HCLPFs is defined as a variable of horizontal component response spectrum shape, so 1.22 to 1.35 of factors can be derived [2]. That is, the Square Root of Square Sum (SRSS) combinations of these randomness and uncertainty (β_{rs}) are determined by 0.2 and 0.3 for the west of the U.S. and the east of the U.S. respectively. Therefore 1.22 (i.e., $e^{0.2}$) and 1.35 (i.e., $e^{0.3}$) of factors are introduced. 1.430 to 1.549 of the factors achieved by this study are somewhat larger than those by the reference because the relationship between the two HCLPFs by the reference is considered only with seismic input motions (i.e., seismic demand terms) but seismic capacity terms between both methodologies are not considered. In other words, in determining seismic capacities consisting of material properties and strength equations, the quantitative factors between both methodologies may exist. In this study, both methodologies utilize material properties of 95% confidence level equally but seismic fragility utilizes strength equations of 95% confidence level, whereas CDFM utilizes those of 84% confidence level. Therefore 1.300 (1.430/1.10) to 1.408 (1.549/1.10) of factors reflecting the increase by capacities can be derived with similar value of 4% to 7% of gap.

Table 1. Factors by Strength Equations in Both Methodologies

Strength Equation		S.F		CDFM	CDFM/S.F
		β	$e^{(-1.65x\beta)}$	Reduction	
Containment Shell		0.15	0.78*	0.85*	1.09
Shear wall	Shear	0.15	0.78*	0.82*	1.05
	Moment	0.15	0.78*	0.90*	1.15
Ave.					1.10

*A reduction rate over median strength

4. Conclusion

Two methodologies, seismic fragility methodology and CDFM methodology are typically used to determine seismic performances of components quantitatively and the seismic performances are represented by HCLPF capacities. In this study quantitative factors are intended to be derived from between the two HCLPFs by both methodologies and in order to achieve this, seismic performances of same components are evaluated by each methodology respectively. The appropriate factors between the two HCLPFs by both methodologies are derived and reviewed by a relative document. By this study the concept of seismic performances which is inherent in each methodology can be recognized precisely and quantitative relationship between both methodologies can be understood in evaluating seismic performances of components.

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