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Comparison of Seismic Design Criteria between Nuclear Standards and Korean Building Codes

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1. Introduction

The seismic design concepts of a Korean Building Code (KBC) and Nuclear Power Plant (NPP) are compared in this study. The seismic design criteria for two structures are compared and design response spectrums are also compared. For some qualitative comparison, the base shear forces were evaluated for NPP seismic design guidelines and KBC design guidelines. The seismic design forces represening a PGA of a nuclear structure and a conventional structure are 0.2g and 0.22g, respectively. The design force of the conventional structures is higher than that of the nuclear structures but their design concept is different. As a result, the seismic loadings are almost 5 times higher for the nuclear structures than for the conventional structures.

2. Seismic Design Criteria of NPP Site

A seismic design of a Nuclear Power Plant (NPP) is performed as a Safe shutdown earthquake (SSE) and Operating Base Earthquake (OBE). The SSE and OBE are defined as below [1]. In Korea, the SSE and OBE levels are decided as 0.2g and 0.1g, respectively. A seismic design spectrum of a Korean NPP follows the design spectrum of NRC reg. Guide 1.60 [2].

Safe-shutdown earthquake (SSE) - that earthquake for which certain structures, systems and components are designed to remain functional. In the past, the SSE has been commonly characterized by a standardized spectral shape anchored to a peak ground acceleration value.

Operating base earthquake (OBE) - that earthquake for which those features of the nuclear power plant necessary for a continued operation without undue risk to health and safety are designed to remain functional. In the past, the OBE was commonly chosen to be one-half of the SSE.

3. Seismic Design Criteria of KBC 2005 [3]

A seismic design load for building structures is decided as 2/3 of a 2400 year recurrence earthquake. A seismic risk coefficient and spectral coefficient are shown in Table 1 and 2, respectively.

Moreover, in the KBC2005, an importance factor should be considered for a seismic design of Building structures. The maximum value of an importance factor is 1.5 for a special level of structures. The special level structures are hospitals, broadcasting stations, fire stations, power plants etc.

Table 1. Seismic Risk Coefficient, I

Return period (year)	50	100	200	500	1000	2400
Risk coefficient (I)	0.40	0.57	0.73	1.0	1.4	2.0

Table 2. Spectral Coefficient

	Seismic Zone 1 (A=0.11)		Seismic Zone 2 (A=0.07)	
	S_{DS}	S_{D1}	S_{DS}	S_{D1}
S_A	2.0MA	0.8MA	1.8MA	0.7MA
S_B	2.5MA	1.0MA	2.5MA	1.0MA
S_C	3.0MA	1.6MA	3.0MA	1.6MA
S_D	3.6MA	2.3MA	4.0MA	2.3MA
S_E	5.0MA	3.4MA	6.0MA	3.4MA

*M=1.33

A seismic design level of conventional structures is also classified as two levels. The seismic design levels are Contingency Level Earthquake (CLE) and Operating Level Earthquake (OLE). A definition of the two level earthquakes is shown as below [4].

The Contingency Level Earthquake (CLE) ground motions are established that have a 10-percent probability of being exceeded in 50 years (corresponding to an average return period of about 500 years). Under this level of a shaking, the structure is designed so as to undergo damage that is controlled, economically repairable, and is not a threat to life safety.

The Operating Level Earthquake (OLE) ground motions are established that have a 10-percent probability of exceedance in 5 years (corresponding to an average return period of about 50 years). Under this level of a shaking, the structure is designed so that operations are not interrupted and any damage that occurs will be reparable in a short time.

Using this guideline, the peak ground acceleration (PGA) for special level structures is evaluated. The PGA of CLE and OLE are 0.22g and 0.08g, respectively.

4. Comparison of Seismic Design Guideline

A design acceleration of NPP and Conventional structures are 0.2g and 0.22g, respectively. It seems like that the design level of a NPP is smaller than that of conventional structures but its design concept is different. The concept of SSE for NPP structures is similar to that of OLE for conventional structures. For the evaluation of more quantitatively, a design spectrum of each seismic design guidelines are compared. A seismic design spectrum of US NRC Reg. Guide 1.60 standard and KBC 2005 for special level of conventional structure are shown in figure 1.

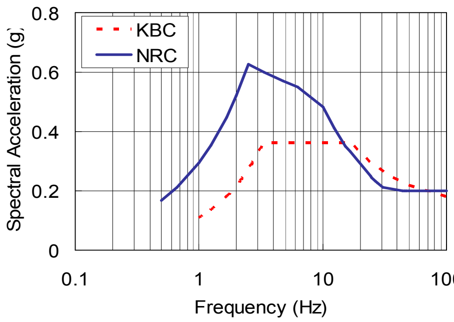

Figure 1. The Design spectrum of KBC and NRC standards

5. Comparison of Base Shear of Containment Structure according to Seismic Design Guideline

To compare a seismic loading for a nuclear and a conventional structure, the base shear forces are evaluated by using each design criteria. For a numerical analysis, the lumped mass model for a Korean Standard Containment structure was used.

The base shear force for conventional structures is evaluated by using equation (1).

$$V = \frac{S_D}{(R/I_E)T} W \qquad (1)$$

where, V is a shear force, R is a response modification factor, I_E is an importance factor, T is a natural period and S_D is a design spectral acceleration. And the base shear force for nuclear structures is evaluated by using equation (2).

$$V = S_D W \qquad (2)$$

But in the case of a numerical analysis, we can easily calculate a base shear force for a simple structure. In this study, a response spectrum analysis was performed using the commercial numerical analysis program MIDAS. The numerical model was constructed as a lumped mass stick model. The numerical model and dimensions are shown in Figure 2 and Table 2, respectively.

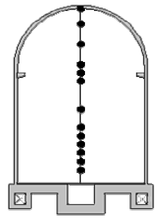

Figure 2. Numerical Model

Table 3. Dimension of Model

Total Weight	29,000ton
Natural Frequency	4.36Hz
Model	elastic

In the case of conventional structures, the design seismic loading can be calculated by only considering the response modification factor. The comparison of the loadings according to the nuclear and conventional structures is summarized in Table 4.

Table 4. Comparison of Seismic Design Loading

	Nuclear Structure	Conventional Structure
Base Shear (tf)	10796.9	10463.1
R factor	0	4.5
Design Force (tf)	10796.9	2325.1
Compare	4.6	1

6. Conclusion

A Korean Building Code was revised recently, and its seismic design guidelines were strengthened. The seismic design forces representing a PGA for a conventional structure are higher than that of a nuclear structure. But nuclear and conventional seismic standards have different approaches regarding the design of civil structures. The seismic design criteria of conventional structures are based on the use of Force Modification Factors to take into account the energy dissipation that occurs in the plastic domain and for utilizing a reserve of strength. But in the case of a nuclear structure, all structures should remain in an elastic domain. As a result, the seismic loadings are almost 5 times higher for the nuclear structure than for the conventional structures.

ACKNOWLEDGEMENT

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