Nonlinear Seismic Behavior of a CANDU Containment Building Subjected to Near-Field Ground Motions

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1. Introduction

The standard response spectrum [1] proposed by US NRC has been used as a design earthquake for the design of Korean nuclear power plant structures. A survey on some of the Quaternary fault segments near Korean nuclear power plants is ongoing [2]. It is likely that these faults will be identified as active ones. If the faults are confirmed as active ones, it will be necessary to reevaluate the seismic safety of the nuclear power plants located near the fault.

Near-fault ground motions are the ground motions that occur near an earthquake fault. In general, the near-fault ground motion records exhibit a distinctive long period pulse like time history with very high peak velocities. These features are induced by the slip of the earthquake fault. Near-fault ground motions, which have caused much of the damage in recent major earthquakes, can be characterized by a pulse-like motion that exposes the structure to a high input energy at the beginning of the motion.

In this study, nonlinear dynamic time-history analyses were performed to investigate the seismic behavior of a CANDU containment structure subjected to various earthquake ground motions including the near-field ground motions.

2. Modeling of the CANDU Containment Building

2.1 Characteristics of the CANDU Containment Building

The containment type of a CANDU nuclear power plant is not tied to the design. The CANDU containment building in Korea, which houses the nuclear reactor and safety related equipments, is a prestressed, post tensioned reinforced concrete structure. The containment consists of a base slab, perimeter wall, ring beam and upper dome. The CANDU containment contains the dousing water of 1,560m^3 in an elevated tank around the building dome for a powerful pressure suppression, not like PWR sprays.

2.2 Analysis Model

A three dimensional finite element model was used for the eigenvalue analysis of the CANDU containment building. A lumped mass model was developed for the nonlinear dynamic time history analysis. The mass of the dousing water was assumed to be attached to the adjacent parts of the domes and the ring beams in each of the analysis model. The fundament frequencies of the containment building by the 3-D FE model and the lumped mass model were 3.86 Hz and 3.84 Hz. This result shows that the lumped mass model can be used to approximate the 3-D FE model for the nonlinear dynamic time history analysis.

2.3 Nonlinear Hysteretic Model

In this study, the tri-linear approximation shown in Fig. 1 was used. The turning points for the shear stress and strain relationship were determined based on the EPJR (Electric Power Joint Research) method [3].

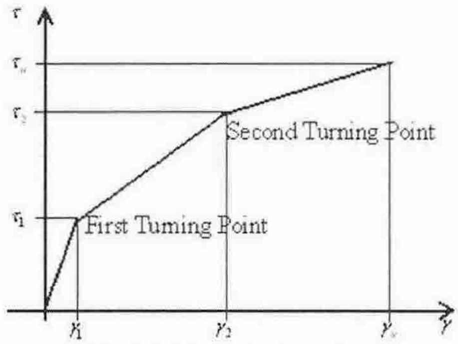

Fig. 1. Trilinear Skeleton Curve

In order to perform the elastoplastic seismic response analysis, based on the trilinear skeleton curve, the maximum point oriented model was used as the hysteresis rule for the repeated unloading and loading process. Fig. 2 shows the hysteresis rule of the maximum point oriented model.

3. Nonlinear Dynamic Analyses

3.1 Input Ground Motions

Three types of input motions, artificial time histories that envelop the US NRC Regulatory Guide 1.60 spectrum [1] and the probability based scenario earthquake [4], and several near-field earthquake records were used for the seismic analyses.

3.2 Nonlinear Response for NRC Design Earthquake

The inelastic nonlinear dynamic analyses of the containment building were performed to investigate the seismic response for the NRC design ground motion. In the design stage, the elastic analysis was performed to obtain the member stress and floor acceleration. The containment building shows a nonlinear response to a design ground motion greater than 0.8g. Fig. 3 shows the shear force – displacement relationship at the lower part of the containment building at 2.0g PGA. It definitely shows an inelastic nonlinear response. Fig. 3 shows the displacement response at the top of the containment building according to the input PGA. It can be seen that the displacement is increased very rapidly after 1.0g PGA (Peak Ground Acceleration) due to the nonlinear response. In contrast to the displacement response, the acceleration response was decreased in comparison to the elastic response.

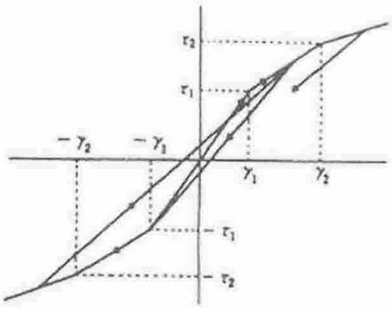

Fig. 2. Maximum Point Oriented Model

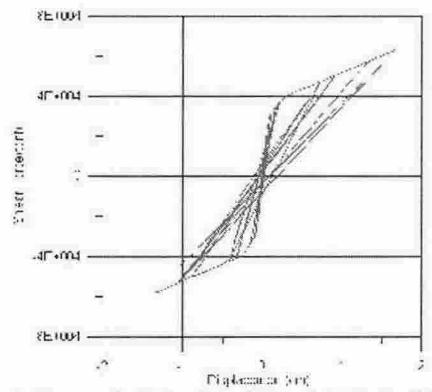

Fig. 3. Hysteretic Behavior of Containment Building

3.2 Nonlinear Response for Near-Field Earthquake

To investigate the seismic behavior of the containment building for the near-filed earthquakes, inelastic nonlinear analyses were performed for several near-field ground motions. Fig. 4 shows the displacement response at the top of the containment building according to the input PGA. The thick black line shows the average displacement response due to the near-field ground motions. It can be seen that the displacement responses due to the design ground motion is greater than those due to the near-field ground motions.

4. Conclusion

In this study, inelastic nonlinear seismic analyses of the CANDU containment building were performed to estimate the seismic response for the design ground motion and several near-field ground motions.

The CANDU containment building shows a nonlinear behavior for the NRC design ground motion greater that 0.8g PGA. The displacement responses due to the near-field ground motions were smaller than those due to the NRC design ground motion. This result shows that the near-field ground motion effect is not so damaging to the containment which is a relatively stiff structure. The containment building shows an elastic behavior for various earthquake ground motions at the SSE (Safe Shutdown Earthquake) level of PGA.

The displacement based seismic fragility analysis is essential to estimate the seismic margin of the containment building when considering the nonlinear dynamic behavior.

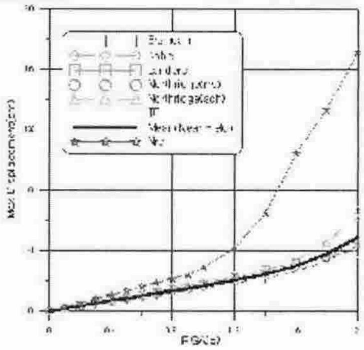

Fig. 4. Maximum Displacement at the Top of the Containment

ACKNOWLEDGEMENT

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