

Safety Reassessments and Actions Taken in HANARO since Fukushima Daiichi Accident

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Abstract. After the Fukushima Daiichi Accident, a special safety review was conducted for all nuclear facilities such as nuclear power plants, research reactors, and nuclear fuel fabrication facilities in Korea, by a special review team organized with government officials, regulators and civilian experts. HANARO, a 30MW research reactor, was also inspected to review the plant design and configuration, operation procedures, the accident management procedures, and the emergency preparedness plan over the design basis accidents and extreme natural events. As the results of the review, several recommendations were given to HANARO for the improvement of the safety. The measures for the recommendations have been implemented and reported to the regulatory body. One of the recommendations made by the special review team was to evaluate the seismic margin of the reactor building. A seismic margin assessment was performed and it showed that some part of the outer wall of the reactor building did not satisfy the seismic design criteria set to 0.2g in horizontal direction. Thus, the regulatory body officially asked a seismic reinforcement of the reactor building and the reinforcement work has been completed recently. This paper describes the summary of the safety reassessment and the actions taken to improve the safety of HANARO since the Fukushima Daiichi Accident.

1. Introduction

A special safety inspection on nuclear facilities in Korea was conducted by the government after Fukushima Daiichi Accident. The safety of HANARO, a 30 MW research reactor, was also inspected by a special review team composed of government officials, regulators, and specialists. The review team primarily reviewed the adequacy of the plant design and the actual conditions of facilities against natural hazards such as earthquake and flooding. And they also checked the normal operation procedures, the emergency operation procedures, and the accident management guidelines over the design basis accidents considered in the safety analysis reports. They finally made several recommendations on the identified issues for the safety improvement as follows [1]:

- To evaluate the seismic margin of the reactor building and exhaust stack for earthquakes beyond the design basis
- To implement a protective measures for operators in the main control room on earthquakes.
- To re-evaluate the site's inundation depth for flooding
- To amend the emergency plan and emergency preparedness program

KAERI implemented the measures for the recommendations and reported the results to the regulatory body. However, the result of seismic margin assessment showed that some part of the outer wall of the reactor building did not satisfy the seismic design criteria, while the exhaust stack and RCI (Reactor Concrete Island) have sufficient seismic margins. The Nuclear Safety and Security Commission (NSSC) of the Korean government ordered KAERI to reinforce the outer wall of the reactor building. Hence, the reinforcement project has been

implemented in order to meet the design basis condition and have the margin [2]. This paper summarizes the results of the safety reassessment and the actions taken for improvement.

2. Safety reassessment and actions for improvement

2.1 Evaluation of the seismic margin of HANARO reactor building.

A Seismic Margin Assessment (SMA) was performed to evaluate the reactor building using the EPRI-NP-6041-SL (A Methodology for Assessment of Nuclear Power Plant Seismic Margin (Rev. 1)), which is one of the official seismic assessment methods authorized by US NRC. The Seismic Margin Earthquake (SME) for SMA was set to PGA 0.3g in horizontal direction, which is 1.5 times of Safe Shutdown Earthquake (SSE) 0.2g. The reactor building was fully modeled in 3D shell and beam elements shown in FIG. 1 for a finite element analysis using SAP2000. Mode shapes and natural frequencies of 3D model of the reactor building were figured out through a modal analysis. Member forces under seismic loads were calculated by a response spectrum analysis using a ground response spectrum shown in FIG. 2, commensurate with NUREG/CR-0098 (Development of Criteria for Seismic Review of Selected Nuclear Power Plants) [3].

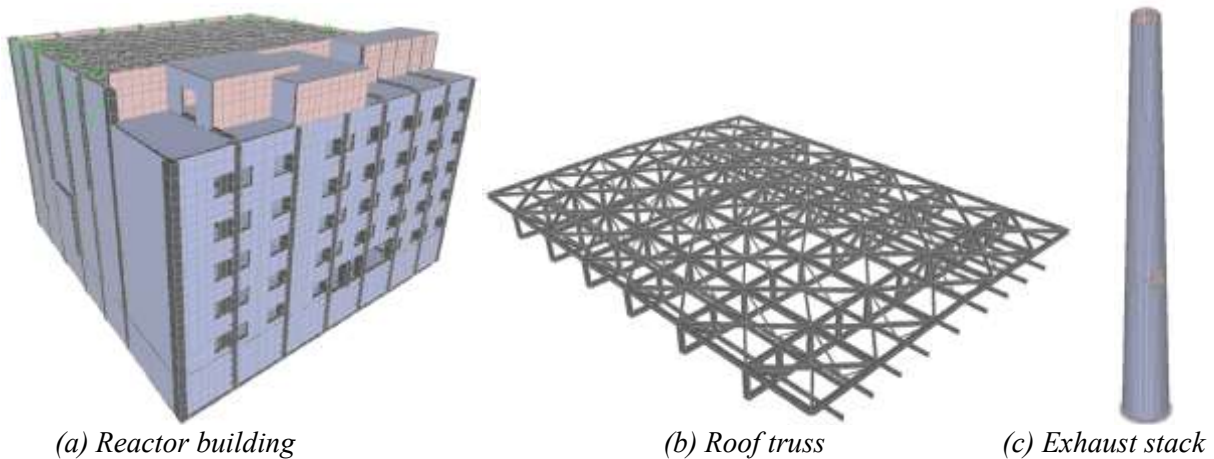


FIG. 1. 3D Model of reactor building and exhaust stack

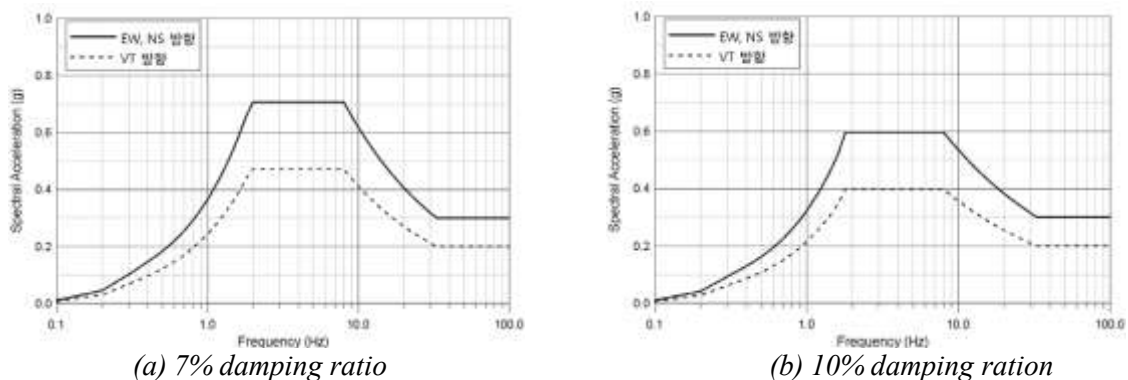


FIG. 2. Ground response spectrum for SMA (PGA: 0.3g horizontal, 0.2g vertical)

The assessment results showed that the Reactor Concrete Island (RCI) which accommodates major reactor systems can withstand 1.71 g earthquake and the seismic capability of the exhaust stack also reaches 0.57 g. However, it was found that some 4.8% of the outer wall of

HANARO building didn't satisfy the required seismic design criteria, which is 0.2 g (Richter Scale 6.5). This is due to the difference in the analysis model for the original design and for the SMA. For the original design, only major structural frames were represented using a beam-stick model, while for SMA, every structural and non-structural component of the reactor building was represented in a 3D detailed modeling [2].

It is well recognized that the HANARO building was designed to satisfy all seismic design criteria subject to the technical standards and procedures at that time it was licensed, and has safely been maintained for over 20 years without any concerns. But new findings were derived from the assessment based on the recent technologies, and the measures for strengthening the safety of the HANARO reactor building became imperative. The result of the seismic margin assessment was reported to the Korean Nuclear Safety and Security Commission (NSSC) on 19 December 2014. The Commission officially recommended KAERI on 19 March 2015 to reinforce some parts of the HANARO outer wall that was identified not to satisfy the seismic requirements.

2. 2 Design of the seismic reinforcement of the reactor building

KAERI immediately started an investigation in order to take necessary measures available to implement the reinforcement of the reactor building. It identified interferences between the HANARO building and the reactor systems which are installed in it, to find possible reinforcement methods. Moreover a lot of building structures and reactor-related systems are complicatedly interconnected around and adjacent to the HANARO building. Therefore, it was difficult to use general reinforcement method that would be applied to normal buildings. A special task force team surveyed every possible reinforcement methods and concluded a reasonable method that satisfies not only seismic performance but also site conditions. The final reinforcement scheme has been produced after careful reviews by the related experts.

Steel H-beams were used to support the wall of the reactor building both from inside and outside as shown in FIG. 3. It was designed that the H-beams can reduce the bending moments that can be induced on the wall of the reactor building under seismic loads. In addition, PS tendon was used for some part of the wall of the reactor building to control the in-plane tensile stress. It was confirmed that the reinforcement concept will be effective based on a dynamic analysis as well as a real scale static test. Through the seismic reinforcement, both the axial and flexural strengths were greatly improved. According to the analysis of the reinforced reactor building, the maximum bending moments after reinforcing are decreased minimum 47% compared with the maximum moments before reinforcing [4,5]. The reinforcement concept above is expected to not only satisfy the required seismic criteria but also have enough margins to withstand beyond design basis earthquake (PGA 0.3g).

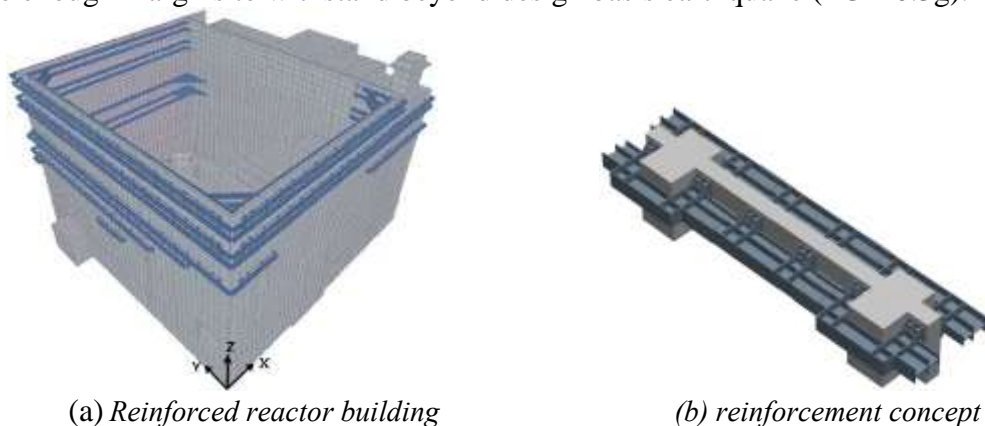


FIG. 3. Reinforced model of HANARO reactor building

2. 3 Implementation of the reinforcement of the reactor building

After completing the reinforcement design and submitting the related documents to the regulatory body, KAERI made a contract with a domestic construction company and commenced the reinforcement work in Feb. 2016. The construction works are various in the field and listed as follows:

- Installation of protection covers for the service pool and spent fuel storage pool
- Installation of scaffolds and safety nets
- Removal of interfering fixtures on the wall
- Measuring the level and coordinates of the wall
- Scanning the positions of re-bars inside the concrete walls
- Drilling the wall to make through-bolt holes
- Installation of through-bolts(filling with non-shrink grout)
- Attaching steel H-beams on the wall using through-bolts
- Reinstallation of detached fixtures
- Installation of exterior finish materials
- Dismantling scaffolds and safety nets
- Removal of protection covers for the pools

All reinforcement works have been completed in April 2017 as shown in FIG. 4. An extensive leak test has been successfully done for the whole reactor building and the results satisfied the required confinement criteria.



(a) Exterior installation

(b) Exterior finish

(b) Interior installation

FIG. 4. Completion of the reinforcement of the HANARO reactor building

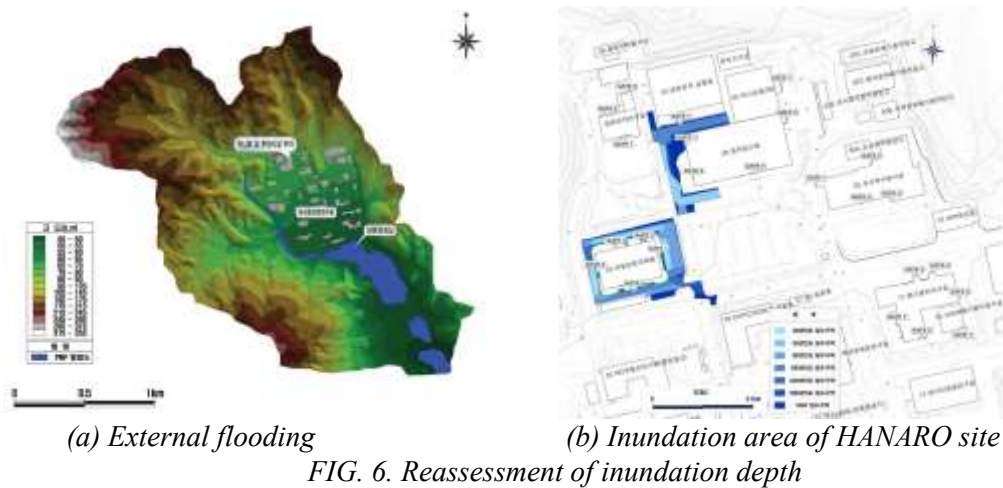
2. 4 Implementation of protective measures for operators in main control room

One of the lessons learned from the Fukushima Daiichi accident is that the operators can be harmed by the fall of ceiling, lighting fixtures, or furnishings of the control room in the event of an earthquake. So it was recommended that HANARO should be improved by taking measures to protect the operators in the control room. In response, HANARO Management Div. identified the non-seismic equipments and furnishings in need of reinforcement in the control room. Then new furnishings and supporting fixtures that meet the seismic requirements, were installed after seismic analysis and design. Lighting fixtures, access floors, console desks, wall cabinets and CCTV monitor cases were replaced as showed in FIG. 5, and seismic reinforcements were installed at halon fire extinguishing cabinets [6]. These improvements have enhanced the seismic capability of the main control room to withstand itself during an earthquake PGA 0.3g (Richter Scale 7.0).



2. 5 Reassessment of inundation depth

Considering the change of rainfall intensity according to the recent climate change, flood level and inundation depth of HANARO site was reassessed when Probable Maximum Precipitation (PMP) occurs. The site’s characteristics such as location and drain system, and historical records of temperatures, humidity, wind velocity, and precipitation, were investigated to estimate PMP. And then Probable Maximum Flood (PMF) was estimated reflecting estimated PMP. The results of the assessment showed that the external flooding from the adjacent river doesn’t affect the HANARO site and the reactor building will not be inundated even when PMF occurs as shown in FIG. 6 [7].



3. Conclusions

KAERI implemented all the recommendations from the government for the safety improvement of HANARO after the Fukushima Daiichi Accident. Most of all, the seismic reassessment and the reinforcement of the HANARO reactor building were great issues. The regulatory body has inspected the whole process for the reinforcement design and works, and the citizen's verification team has also inspected the results after the completion of reinforcement works. Now HANARO is waiting for the regulatory authority's approval for the re-operation and hopes to contribute to the country and the people again as a large scale research facility.

4. References

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