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Development of Three Dimensional Seismic Isolator for Nuclear Facility Components

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1. Introduction

Securing the safety of nuclear power plants has become an important issue, after the last Fukushima nuclear power plant accident. Seismic isolation technology using laminated rubber bearing (LRB) has been studied as a solution for those kinds of accidents. The LRB is a repeatedly laminated form of rubber-metal and provides seismic isolation effect for horizontal direction [1, 2]. However it does not serve the seismic isolation on the vertical direction, it is necessary additional components. So the research and development have been conducted on the 3 dimensional seismic isolation systems for the reduction of seismic responses, including vertical directions as well as horizontal direction [3]. The Korea Atomic Energy Research Institute is developing a three-dimensional seismic isolator that consists of spring-damper system based on a lead-inserted small laminated rubber bearing which is improved from the laminated rubber bearing. The isolator is designed to react to the earthquakes in horizontally with LRB and to react to the earthquakes in horizontally vertically with a spring-damper system. In this paper, the feasibility of steel damper design to be installed in the 3D seismic isolator was evaluated through finite element method and performance tests.

2. Three Dimensional Seismic Isolator

Figure 1 shows the three-dimensional seismic isolator being developed in this study. Small laminated rubber bearing reacting to an earthquake in the horizontal direction is placed at the lower part of isolator, and spring-damper system, which are the part reacting to an earthquake in the vertical direction, are installed inside the housing at the upper part of isolator. When an earthquake occurs, the LRB deforms in the horizontal direction, and the spring-damper system deforms in vertical direction and the the upper housing slides along the side of the flange connected to the LRB. The isolator is designed for the mass of 1 ton and target frequency of 3 Hz.

3. Design and Test of Steel Damper

It is difficult to disassemble and inspect or repair it again, after the isolator is installed in a devices such as cabinet or subracks, so the hydraulic dampers or dashpots which are widely used are not applicable. In this study, we decided to use a steel damper in the consideration of maintenance, and the shape was made as simple as possible [4].

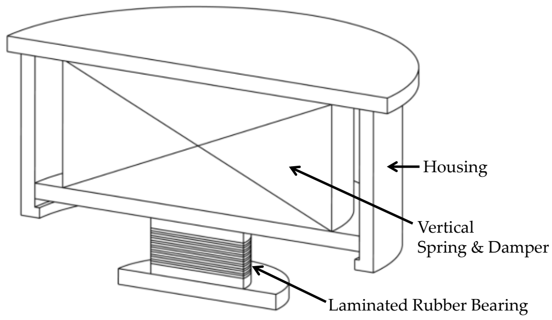

Figure 1 Schematic of 3D seismic isolator (half section view)

Table 1 Design Parameters of 3D Seismic Isolator

Device	Parameters	Value
Horizontal seismic isolation device (LRB)	Outer diameter	100 mm
	Lead plug diameter	21.5 mm
	Total height	34 mm
	Shape factor(S1, S2)	9.9, 5.0
	Design vertical load	10 kN
Vertical seismic isolation device	Outer diameter	450 mm
	Total height	140-360 mm
	Design vertical load	10 kN

3.1 Design of Steel Damper

The performance of the cantilever type steel damper is determined by the shape, and the shape of the steel damper in this study is as shown in the figure. Numerical analysis was performed by changing the horizontal dimensions of the damper, H1, H2, and H3, the vertical dimensions, V1, V2, V3, and the width, W. The vertical tip displacement acting on the steel damper was +-24 mm, and Type 316H Stainless Steel was used as a material for the steel damper. Figure 2 shows the hysteretic graph of the vertical displacement-reaction force obtained from the analysis. As a result of design analysis, it was confirmed that each steel damper has a critical damping ratio of SD1=35.17%, SD=35.25%, and SD3=31.7%.

3.2 Performance Tests

A test was performed to verify the hysteretic performance of the designed steel damper. Each damper was installed on a jig and cyclic loading tests were performed. Loads were applied using an universal testing machine, INSTRON 5982 and the test data were recorded using an acquisition program, INSTRON Bluehill 3. The test displacements were applied with +-24mm and +-30mm, and the displacement control speed was set to 5mm/min in consideration of the quasi-static condition. Figure 3 shows the verification test for steel dampers. Comparing the hysteretic curve from the test with the graph obtained from the FEM analysis, it is almost exactly the same, and it is expected to show a damping performance of 30%.

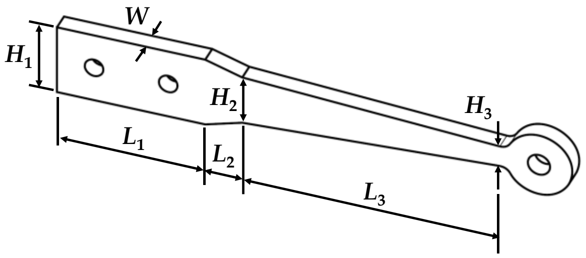

Figure 2 Dimension parameters of steel damper

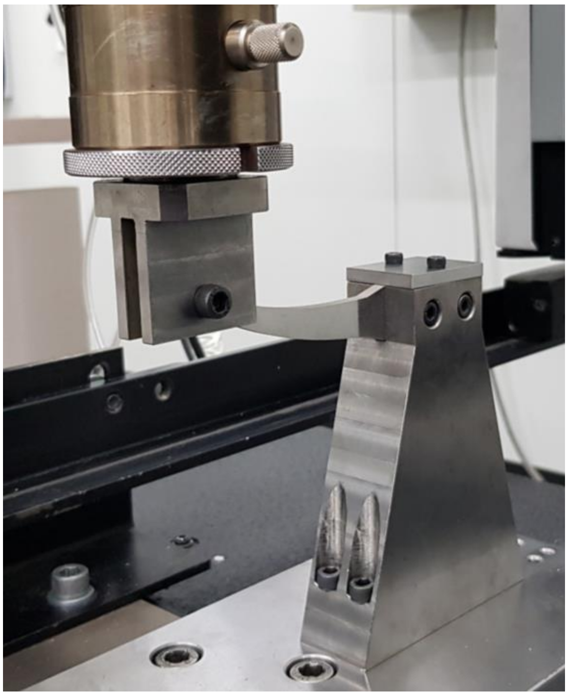

Figure 3 Verification test for steel dampers

3.3 Evaluation of Vertical Seismic Isolation

The vertical seismic isolation performance using a steel damper was evaluated in consideration of the limited vertical displacement of the upper structure of the seismic isolator. According to the analysis result, it was confirmed that 5 or more should be used for SD1, 4 for SD2, and 2 or more for SD3.

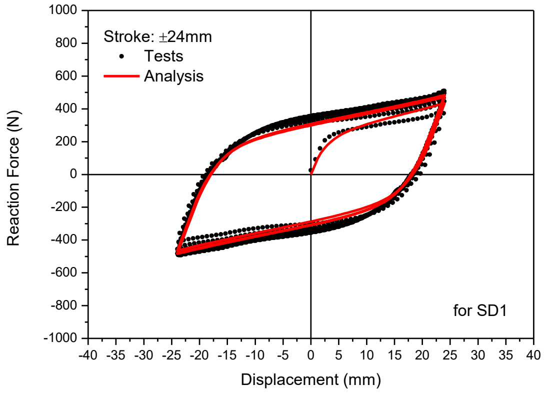

Figure 4 Comparison of hysteretic behavior between test and analysis (SD1)

4. Conclusion

In this paper, the steel damper applicable to the 3D seismic isolator under development was studied. Three types of steel dampers were proposed and their characteristics were verified through analysis and experiments. It was confirmed that the steel damper decreases the seismic response in the vertical direction with the allowable design range, and in the case of the SD3 damper, the required performance can be sufficiently exhibited with three dampers.

REFERENCES

[1] G. H. Koo, J. Y. Jung, J. H. Lee, T. M. Shin, Development of small-sized lead inserted laminated rubber bearing for nuclear component seismic isolation, Energies, 13, p.3193, 2020.

[2] M. Morishita, S. Kitamura, S. Moro, Y. Kamishima, Y. Takahiro, Study on 3-dimensional seismic isolation system for next generation nuclear power plant-vertical component isolation system with coned disk spring, Technical Report No. 620 In Proceedings of the 13th World Conference on Earthquake Engineering, Vancouver, BC, Canada, 1-6 August 2004.

[3] Y. Okada, J. Suhara, T. Tamura, K. Ohta, S. Moro, Development of Three Dimensional Seismic Isolation Device with Laminated Rubber Bearing and Rolling Seal Type Air Spring, In Proceedings of the GENES4/ANP 2003, Kyto, Japan, 15-19 September, 2003.

[4] G. H. Koo, J. Y. Jung, J. K. Hwang, T. M.Shin, M. S. Lee, Vertical Seismic Isolation Device for Three-Dimensional Seismic Isolation of Nuclear Power Plant Equipment-Case Study, Applied Sciences, 12, 320, 2022.