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Experimental Study on a Prototype Seismic Isolation Device for NPP

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1. Introduction

Concerns about seismic safety with regard to the structure of nuclear power plants have multiplied since the major earthquake that occurred in eastern Japan in 2011. The seismic safety of NPP structures is generally completed by seismic design, but seismic safety can be upgraded by raising the present 0.2g seismic design condition to 0.3g, and by adopting such seismic isolation designs as those of the four Cruas NPPs in France and the two Koeberg NPPs in South Africa. In this context, a seismic isolation device was developed with a view to upgrading the seismic safety of Korean standard NPP, and the proposed device was subjected to various performance evaluations.

2. Concept of Application of Seismic Isolation

Korean standard NPPs were designed by applying a 0.3g seismic design, and a corresponding seismic isolation device was developed to resist peak ground acceleration up to 0.5g. The seismic isolation device was designed to apply a total of 527 LRBs (Lead Rubber Bearings) in a nuclear island (NI) area, as shown in Fig 1.

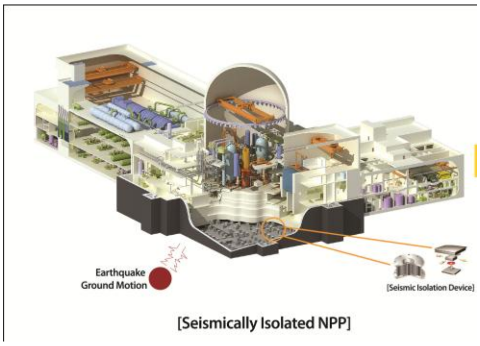


Fig. 1. Diagram of Concept of Seismic Isolation of NPP

The total weight of the upper structure is about 450,000 tons; its seismic isolation period is 2.3 seconds; the diameter of the LRB seismic isolation device is 1,500 mm; and the design displacement is 224 mm.

- Target period: 2.3 sec
- Design displacement: 224mm
- Weight of the super-structure: approx. 450,000 tons
- Diameter of LRB: Φ 1,500 mm

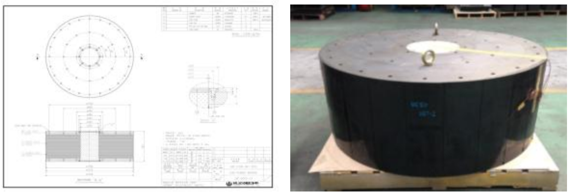


Fig. 2. Drawing and photo of final product

3. Performance Test and Results

3.1 Basic Characteristics Tests and Results

In the seismic isolation device test, the compression and shear characteristics between design and test results are compared.

The compression and shear characteristics shall be within ±30% and ±10%, respectively, compared to the design conditions. In the results of the basic characteristics tests, compression and shear stiffness showed an error rate of 10.1% and 4.4%, respectively, thus meeting the standard values.

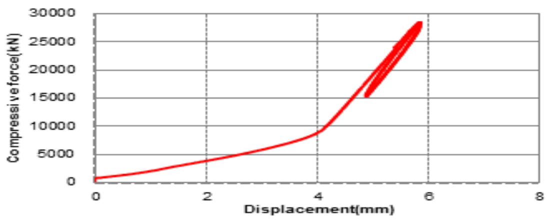


Fig. 3. Compression Stiffness Characteristics Test Result (Displacement – Force)

Table 1 : Compression Characteristics Test Result

Division	Unit	Max	Min
Compression Force	kN	28,504	15,340
Displacement	mm	5.869	4.880
Compression stiffness	kN/mm	13,314	
Standard value	kN/mm	12,090±30%	
Error rate	%	**10.1 (Satisfied)**	
Displacement quantity	mm	0.988	

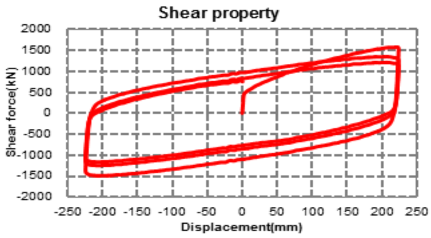


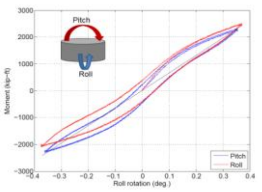
Fig. 4. Shear Characteristics Test Result (Displacement –Shear Force)

Table 2 : Shear Characteristics Test Result

Division	K_h (kN/mm)	H_{eq} (%)
Standard value	5.983±10%	30.2-Over 15%
Test Result	5.72	33.3
Error rate	-4.4%	+10.26%
Judgment	Satisfied	Satisfied

3.2 Special Performance Evaluation

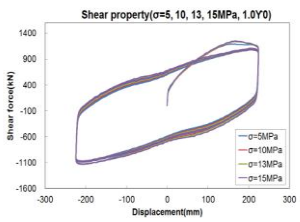
Pitch and roll tests were performed to evaluate the rotational characteristics of the seismic isolation device. Pitch and roll tests are designed to evaluate the characteristics on the direction property as enforcing the force to ±0.35 degree to the x-direction and to ±0.35 degree to the y-direction respectively. As a result of the test, the deviations in two directions showed within 10%, so this showed that the rotational characteristics of the two axes were well matched.



Direction	Rotation (Deg.)	Moment (kip-ft)
Pitch	-0.36	-2,150
	+0.36	+2,230
Roll	-0.36	-2,050
	+0.36	+2,400

Fig. 5. Results of Pitch-Roll Characteristics Test

To evaluate the dependence of shear characteristics on compressive forces, characteristics tests towards 5MPa~13MPa of compression stress were performed. There were almost no changes of shear stiffness when the compression stress was increased, but a small increase occurred as the shear characteristics on compressive forces became higher in case of equivalent damping ratio.



σ(MPa)	Shear Stiffness (kh)	Equivalent Damping Ratio (heq)
5	5.821kN/mm	0.305
10	5.797kN/mm	0.315
13	5.770kN/mm	0.328
15	5.623kN/mm	0.330

Fig. 6. Result of Test of Dependence of Shear Characteristics on Compressive Forces

A rupture test was performed to evaluate the limit performance of the seismic isolation device. The rupture test is divided into the rupture test by monotone increasing force and the dynamic rupture test. Generally speaking, more limit variations are come from the rupture test by monotone increasing force. This study was performed by the rupture test by circle shape dynamic force. Fig 7 shows a photo of the rupture test; and as the test result, the device was ruptured at 1,090mm of displacement, which is 4.87 times of design displacement (224mm).

This limit performance is recognized as an important result with regard to the application of the proposed seismic isolation device to NPPs. Namely, seismic isolation devices in NPPs require a higher performance limit than the seismic isolation devices used for general bridges or structures. Fig 8 shows the behaviors in a rupture situation.

Fig 7. View of Rupture Test

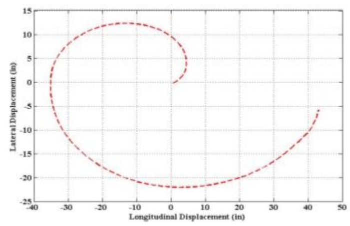


Fig. 8. Results of Rupture Test Behavior

4. Conclusions

This study entails the development of an LRB seismic isolation device for application to NPPs, and an evaluation of its performance. The excellence of the developed seismic isolation device was proven by subjecting it to basic characteristics tests and various special performance evaluations. Notably, 487% performance comparing to design variations was proven in limit performance evaluation. Thus, the seismic isolation device proposed in this study is judged to be suitable for application to NPPs intended for export in the future.

ACKNOWLEDGMENTS

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