Transactions of the Korean Nuclear Society Autumn Meeting
Gyeongju, Korea, October 24-25, 2013

Assessment of LRB Seismic Isolation Device for Nuclear Power Plant

Hong-Pyo Lee [a*], Myung-Sug Cho [a], Jin-Young Park [b], Kwang-Seok Jang [b]
[a]*KHNP-CRI, 1312-70, Yuseong-Daero, Yuseong-Gu, Daejeon, Korea, 305-343*
[b]*UNISON e-Tech, 53, Ugakgolgil, Sooshinmyeon, Dongnamgu, Cheonan, Korea, 330-882*
[*]*Corresponding author: hplee@khnp.co.kr*

1. Introduction

Because its importance is especially high in the case of structures in a nuclear power plant (NPP), the application of seismic protection to such structures requires an extremely reliable seismic protection isolator. Lead rubber support series is representative among the isolators recommended for the structures in NPP.

Lead Rubber Bearing (hereafter referred as 'LRB'), which is a lead rubber support series, is a seismic protection isolator that is manufactured using rubber and steel layered crosswise with a lead rod inserted in the central part. It is manufactured as a circular type, reducing the excess horizontal load. It is applied in lower support structures, allowing horizontal movement at the same time as supporting vertical loads safely, as well as in upper support structures in architectural and civil facilities.

Through this study, the levels of general characteristics of LRB on performance of the tests required in ISO 22762-1 such as compression and shear characteristics, and reaction in extreme conditions, are identified, and the results will also be utilized in future as reference data for the design and manufacture of relevant products.

2. Introduction to the Test

2.1 Specification of the Test Specimen

The specifications of the test specimen were determined as outer diameter 520mm (lead rubber outer diameter: 500mm and cladding rubber thickness: 20mm), cored lead diameter 90mm, and G=0.392MPa. The primary and secondary shape factors of the specimen were designated as 37.9 and 5.1 respectively.

2.2Test Equipment

The tester used in the characteristics experiment of the LRB test specimen is a compression-shear tester shown in Fig. 1. The maximum vertical load is 30,000kN and the maximum horizontal load is 500kN. The maximum horizontal acceleration velocity is 20 mm/sec and the maximum horizontal direction displacement is ±1,000mm.

2.3 Test Item

To check the dependency of shear stiffness according to shear strain and equivalent damping ratio in LRB, the compression-shear experiment was performed under that condition of shear strain of $0.5\gamma_0$, $1.0\gamma_0$, $1.5\gamma_0$, $2.0\gamma_0$, $2.50\gamma_0$, $3.0\gamma_0$, $3.5\gamma_0$ and $4.0\gamma_0$. Further, to check the limits of performance, the experiment was performed with a shear strain of $4.5\gamma_0$ and $5.0\gamma_0$ at design bearing pressure [1][2].

Fig. 1 View of Test Equipment

3. Test Result

3.1 Compression Characteristics Test Result

The compression characteristics test of the test specimen was performed according to ISO 22762-1 6.2.1.5 66 (Method 2), and measurements were taken within the variation of ±30% of vertical loads of design bearing pressure, 13MPa (2,253kN). The test velocity was given as 100N/sec. Fig. 2 shows the characteristics graph according to compression tests, and Table I shows the compression characteristics test result. The design value of compression stiffness is 2.495kN/mm, and it is verified that this can be accepted because the measuring efficiency shows 5.75% on comparison with test result.

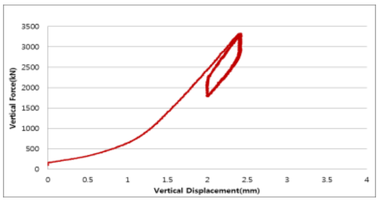

Fig. 2 Characteristics Graph according to Compression Test

Table 1 Compression Characteristics Test Result

P1 (kN)	P2 (kN)	Y1 (mm)	Y2 (mm)	Compression Stiffness (Kv) (kN/mm)
2269.13	3324.54	2.025	2.425	**2.6385**

3.2 Shear Characteristics Test Result

The shear characteristics test of the test specimen was performed according to ISO 22762-1 6.2.2, and towards shear strain of $0.5\gamma_0$, $1.0\gamma_0$, $1.5\gamma_0$, $2.0\gamma_0$, $2.50\gamma_0$, $3.0\gamma_0$, $3.5\gamma_0$ and $4.0\gamma_0$ (γ_0= 99mm). The shear test was performed at a velocity of 0.005Hz sine wave. Fig. 3 shows the test result on 100% shear strain towards design bearing pressure of 13MPa, and the overall test results are shown in Table II. The design value of shear stiffness at design bearing pressure is 1.325kN/min and it is verified that this can be accepted because the measuring efficiency shows 8.78% on comparison with test result.

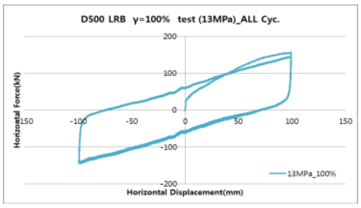

Fig. 3 Load-Displacement History Curve

3.3 Limit Performance Test Result

The limit shear test was performed according to ISO 22762-1 6.4, and was performed towards shear strain of 450% and 500%. In the case of shear strain of 500%, the test was performed at minimum axial force (300kN) in the tester due to safety reasons. The test velocity was applied in the same way as in the shear characteristics test method. No buckling appeared in the limit performance test results either at 450% or 500% shear strain. Also, no internal or external damage occurred. Thus, it is judged that the function as a seismic protection isolator can be achieved fully in the event of an earthquake having a large relative displacement. Fig. 4 and Fig. 5 show limit performance test result at a shear strain of $4.5\gamma_0$ and $5.0\gamma_0$ respectively, while Fig. 6 shows a view of the extreme shear test.

3.3 Limit Performance Test Result

The limit shear test was performed according to ISO 22762-1 6.4, and was performed towards shear strain of 450% and 500%. In the case of shear strain of 500%, the test was performed at minimum axial force (300kN) in the tester due to safety reasons. The test velocity was applied in the same way as in the shear characteristics test method. No buckling appeared in the limit performance test results either at 450% or 500% shear strain. Also, no internal or external damage occurred. Thus, it is judged that the function as a seismic protection isolator can be achieved fully in the event of an earthquake having a large relative displacement. Fig. 4 and Fig. 5 show limit performance test result at a shear strain of $4.5\gamma_0$ and $5.0\gamma_0$ respectively

.

Table 2 Shear Characteristics Test Result

Strain	Q_d (kN)	K_d (kN/mm)	K_{eq} (kN/mm)	EDC
$0.5\gamma_0$	51.688	1.061	2.109	10032.57
$1.0\gamma_0$	58.673	0.848	1.434	23348.21
$1.5\gamma_0$	63.991	0.743	1.174	37203.66
$2.0\gamma_0$	63.219	0.712	1.032	51732.59
$2.5\gamma_0$	67.996	0.703	0.978	71425.09
$3.0\gamma_0$	No buckling or internal & external damage (3Cyc. Completed)			
$3.5\gamma_0$	No buckling or internal & external damage (3Cyc. Completed)			
$4.0\gamma_0$	No buckling or internal & external damage (3Cyc. Completed)			

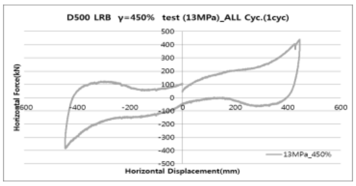

Fig. 4 Limit Performance Test Result ($4.5\gamma_0$)

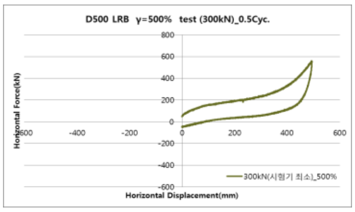

Fig. 5 Limit Performance Test Result ($5.0\gamma_0$)

4. Conclusion

This study evaluates compression stiffness, shear stiffness, and equivalent damping ratio in a specimen LRB performance test for the application of a seismic protection isolator in NPP structures, and also reviews their dependency according to shear strain. To evaluate the safety on relative displacement, an extreme shear test was performed. Based on the results of the compression and shear characteristics tests, it is judged that they meet the measuring efficiency range conditions which are presented in ISO 22762.

ACKNOWLEDGMENT

This work was supported by the Energy Efficiency & Resources of the Korea Institute of Energy Technology Evaluation and Planning(KETEP) grant funded by the Korea government Ministry of Knowledge Economy (No. 2011T100200081)

REFERENCES

[1] ISO 22762-1, Elastomeric Seismic Protection Isolations Part 1: Test methods, 2010.
[2] ISO 22762-3, Elastomeric Seismic Protection Isolations Part 3: Applications for buildings — Specifications, 2010.