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An experimental study on the repeated shear performance of Full-Scale LRB

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ABSTRACT

The series of major earthquakes and tsunamis that hit Tohoku, Japan has led to a growing need for base isolation systems around the world. In particular, the response displacement of structures during earthquakes can have a greater effect than the design displacement of base structures. As such, it is crucial to examine the characteristics of base devices that have been subject to earthquakes for a long period of time. In general, base devices require stability in hysteresis curves for shear deformation, which is expected to arise from long-term load and short-term load (two-fold of a general long-term load) during earthquakes. To determine the shear characteristics from repeated shear behavior of LRB, we conducted 250 repeated shear loading with 100% shear deformation of a life-size LRB base device. The accumulated displacement loaded on the specimen was 224 m, and this varied according to its hysteretic characteristics. For an analysis of actual response by base structures during earthquakes, an evaluation of hysteretic characteristics in relation to repeated behavior is required.

1. INTRODUCTION

Ever since the 1995 Southern Hyogo Prefecture earthquake, the number of base structures has greatly increased. They are used not only in buildings, but also in bridges and industrial plants all over the world. Many studies have been conducted on the dynamic behavioral characteristics of lead rubber bearing (LRB), which is one of the most commonly used seismic isolation devices. While there has been some experimental assessment of repeated stress load and long-term creep deflection, Korea has not been involved in research on the characteristics of repeated shear behavior. In accordance with compression-shear experimental methods specified under ISO22762, this study performed 250 repeated shear cycles using a life-size LRB and analyzed changes in LRB shear characteristics.

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2. EXPERIMENTAL PROGRAM

2.1 Experimental Overview

To determine shear characteristics and changes in energy absorption capacity with repeated shear behavior of the LRB, we carried out 250 repeated shear loading cycles at 100% shear deformation. Repeated shear loading was administered in accordance with compression-shear experimental methods specified under ISO22762-1. The compression stress was maintained at the design surface pressure of 13MPa throughout the experiment. In consideration of performance, the internal temperature was stabilized after 100 cycles at 100% shear deformation, followed by the remaining 150 tests. The accumulated displacement of the base device from repeated shear loading was 224 m.

2.2 Experimental Equipment

The life-size LRB base device used in the repeated shear experiment is shown in Fig. 1. The experimental equipment has a maximum horizontal displacement of ±1,000mm and a vertical load of 30,000kN. Details are given in Table 1.

Fig. 1 30,000kN experimental equipment

Table. 1 Details of experimental equipment

Type	Vertical	Horizontal	Moment
Max. load	30,000kN	±5,000kN	±500kN
Max. displacement	200mm	±1,000mm	±100mm
Max. speed	1mm/sec	20mm/sec	±1000kN.mm

2.3 Specimen

The specimen is shown in Fig. 2, and its specifications in Table 2. The rubber material used in the LRB specimen was natural rubber with G=0.4MPa, which is the same as those used in general buildings. The specimen has an external diameter of 1100 mm (excluding the 10 mm rubber cover), a lead diameter of 240 mm, and a total rubber thickness of 244 mm.

3. EXPERIMENTAL RESULTS

The repeated shear experiment for the life-size LRB base device was carried out under a constant compression load of 13MPa (11,766kN). 100 cycles were performed for a shear displacement of ±224mm, which corresponds to 100% shear deformation rate. After stabilizing the temperature, 150 cycles were carried out for the same shear deformation rate. The shear rigidity (K_{eff}) and equivalent damping ratio (h_{eq}) were measured according to the number of repeated shear loading. The hysteresis loop results are shown in Fig. 3 and Fig. 4.

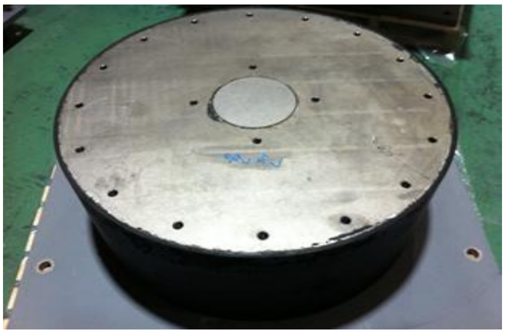

Fig. 2 LRB specimen

Table. 2 Specifications

Rubber material	Natural rubber (G=0.392N/mm2)
External diameter	1100mm
Lead size	240mm
Rubber layer	7.0mm × 32 layers
Inner sheet	4.5mm × 31 layers
Shape factor	S_1=39.3, S_2=4.9

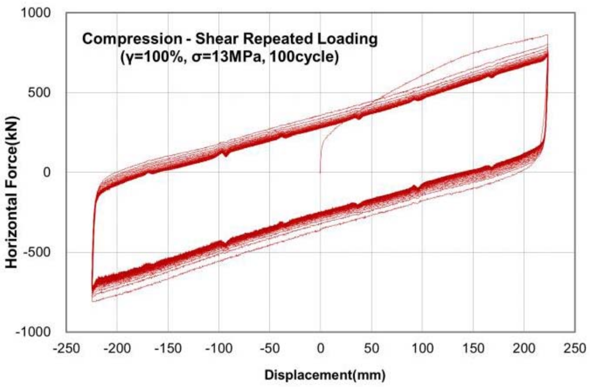

Fig. 3 Hysteresis loop (γ=100%, 100 Cycle)

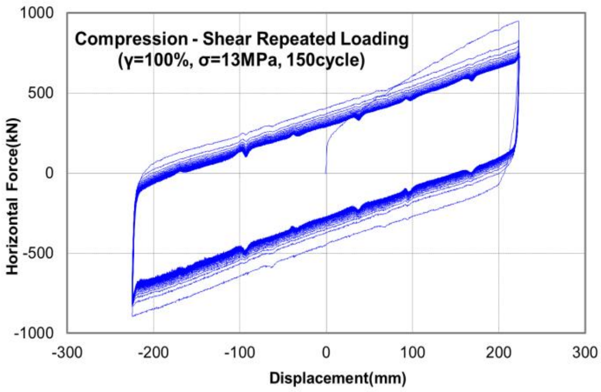

Fig. 4 Hysteresis loop (γ=100%, 150 Cycle)

Table. 3 Result of 100cycle

Cycle	k_{eff}(kN/mm)	Damp. Ratio
10	3.257	0.256
20	3.221	0.247
30	3.257	0.244
40	3.235	0.244
50	3.210	0.244
60	3.217	0.242
70	3.268	0.242
80	3.264	0.240
90	3.264	0.240
100	3.333	0.239

Table. 4 Result of 150cycle

Cycle	k_{eq}(kN/mm)	Damp. Ratio
10	3.270	0.264
20	3.239	0.257
30	3.252	0.253
40	3.279	0.247
50	3.227	0.249
60	3.292	0.254
70	3.283	0.244
80	3.270	0.243
90	3.248	0.255
100	3.275	0.241
110	3.327	0.239
120	3.353	0.240
130	3.344	0.239
140	3.332	0.238
150	3.375	0.237

As can be seen from the results for 150 cycles in Table 4, an increase in repeating frequency leads to an increase in shear rigidity but a decrease in equivalent damping ratio. After 150 cycles, the shear rigidity rose by 3.11%, while the equivalent damping ratio dropped by 11.13%. Graphs for shear rigidity and damping ratio by repeating frequency are presented in Fig. 5 to Fig. 8.

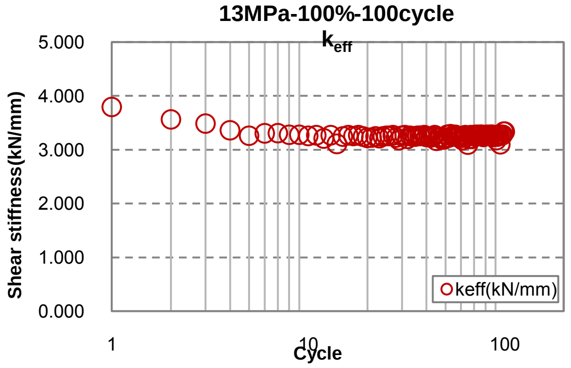

Fig. 5 Change in shear rigidity with repeated shear loading (100cycle)

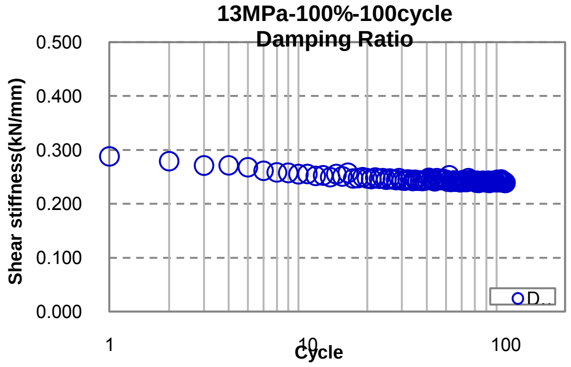

Fig. 6 Change in equivalent damping ratio with repeated shear loading (100cycle)

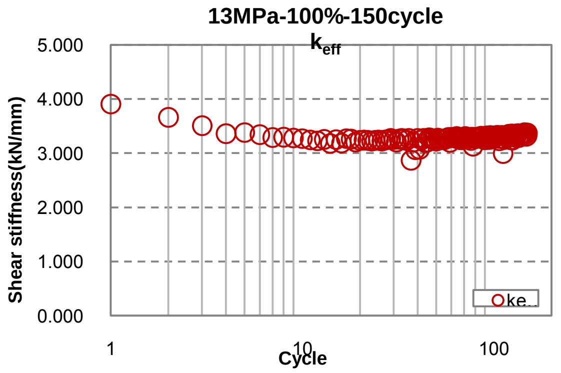

Fig. 7 Change in shear rigidity with repeated shear loading (150cycle)

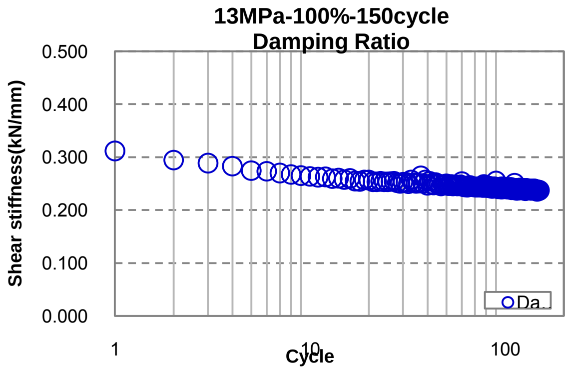

Fig. 8 Change in equivalent damping ratio with repeated shear loading (150cycle)

Changes in the early cycles are more pronounced in the hysteresis curves of the base device, and those after the third cycle are regarded as representative characteristics. The life-size LRB used in this experiment exhibited outstanding behavioral characteristics from long-term repeated shear loading with a 3% change in shear characteristics and 11% change in damping ratio after 250 cycles. The increase in temperature of the lead core, which determines the energy absorption capacity of LRB, is seen as the cause of a decrease in damping ratio.

4. CONCLUSIONS

This study performed 250 cycles of repeated shearing at 100% shear deformation to determine shear characteristics and energy absorption capacity from repeated shear loading on a life-size LRB. The hysteresis characteristics of the specimen varied with repeating frequency. A higher repeating frequency led to an increase in shear rigidity and a decrease in equivalent damping ratio. Base devices tend to have poorer performance with repeated deformation during a prolonged earthquake, and an evaluation of device characteristics is necessary to analyze actual response during earthquakes.

5. ACKNOWLEDGMENT

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REFERENCES

ISO 22762-1. (2010) Elastomeric Seismic Protection Isolations Part 1: Test methods, 2nd Ed., Genova.

Takayama, M., Morita K. (2012) Seismic Response Analysis of Seismically Isolated Buildings using Observed Records due to 2011 Tohoku Earthquake, Lisbon in Portugal 2012 : The 15th World Conference on Earthquake Engineering.