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Study on the Performance Diagram of Multi-Lead Core Rubber Bearing for NPPs

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1. Introduction

The application of lead rubber bearing (LRB) system is able to secure the large shear deformation and high axial load's stability for nuclear power plants[1].

Typically LRB is having a large shear displacement performance. But when the general LRB applied for nuclear power plants, it was increase the quantity of device and a spaced arrangement get narrow.

In this paper, a manufacture full-scale specimen and evaluated the performance testing in variable axial load & shear displacement with the LRB in previous use for architecture. This LRB is applied to the improved rubber material and applied the multi-lead core.

Also it was verified the no effect the design performance properties about multi-lead the compare with design characteristics.

2. Test Overview and Design Specification

2.1 Test Overview

In the used in this paper, testing machine is the axial-shear component with a maximum axial load is 30,000kN and maximum longitudinal load is 5,000kN. It has 20mm/sec in maximum longitudinal loading rate and maximum displacement is ±1,000mm. The machine is able to compressing and shearing and single isolator type in same as figure.8 in ISO 22762-1[1].

In case of the extract performance diagram test, a test conditions are shear displacement of 1.0×D_d, 2.0×D_d, 2.5×D_d, 3.0×D_d, 3.5×D_d under the variable axial load (6 MPa, 13 MPa, 25 MPa). Where, D_d is the design displacement.

The basis of selection's shear displacement was considered the capacity of test machine.

Fig. 1. Testing Machine

2.2 Design Specification

The specification (Table 1) of specimen is applied to full-scale for nuclear power plant which have 1,500mm diameter and 200mm-4axis lead core. And the modulus of rubber is 0.5MPa.

Table 1: Specimen Specification

Rubber	Natural Rubber (G=0.5MPa)
External Dia.	1500 mm
Lead Dia.	200 mm
Num. of Lead	4 EA.
Rubber Layers	7.0 mm × 30 layers
Steel Layers	7.0 mm × 29 layers

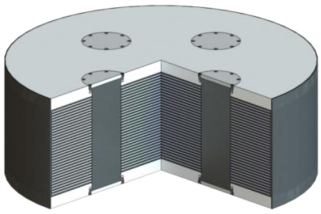

Fig. 2. Concept of Multi-lead Rubber Bearing (MLRB)

3. Test Result

3.1 Axial Characteristics

A load the test specimen with three cycles of axial load between P2 and P1, which are equivalent to plus/minus a certain percent (±30%) in axial characteristics test[2].

Axial characteristic test results are shown in Table 2. Test result is appeared the error rate of 8.4%. It was satisfied result in ISO 22762:3[3].

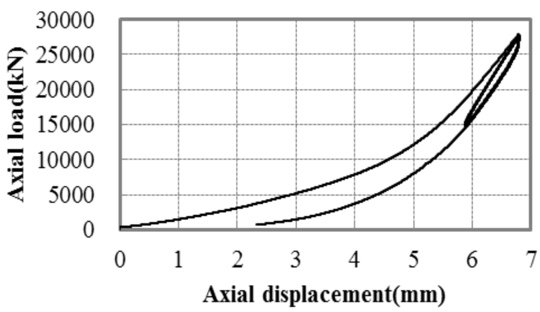

Fig. 3. Axial Characteristic Curve

Table 2: Result of Axial Test

Item	Unit	Value
Design	kN/mm	12,896
Experimental	kN/mm	13,982
Error Rate	%	+8.4

3.2 Longitudinal Characteristics

For longitudinal characteristic test, the cyclic loading of the design shear displacement ($1.0\times D_d$) which shall be carried out for three cycles under axial stress of 13MPa. Longitudinal characteristic test results are shown in Table 3.

When the result's compared a design and experiment, the effective stiffness was appeared the error rate of -8.5% and equivalent damping ratio was +9.6%. According to ISO 22762:3, it was satisfied result.

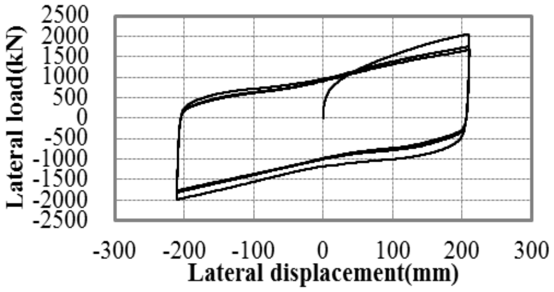

Fig. 4. Longitudinal Characteristic Curve

Table 3: Result of Longitudinal Test

Item	Design	Experiment
Q_d (kN)	1001.77	950.737
K_2 (kN/mm)	4.2	3.978
K_{eff} (kN/mm)	8.973	8.207
H_{eq}(%)	0.332	0.364

3.3 Extract the Performance Diagram

When the failure is tested on rubber bearing, there are appeared the failure mode in generally as follows.

According to the gradually increase of axial load & shear displacement, the hysteresis loop is changed from linear curve to non-linear curve. Subsequently the hysteresis loop is reversed and the bearing is buckled.

In this test, it was evaluated the performance under three case axial load (6MPa, 13MPa, 15MPa) and shear displacement of $1.0\times D_d$~$3.5\times D_d$. Fig. 6 shows the performance diagram of full-scale Multi-lead core rubber bearing (D1500).

From the test results, it was appeared stable behavior in 15MPa (Design axial load $\times$ 2.5) and $3.5\times D_d$.

Fig. 5. Test photo of $D_d \times 3.5$

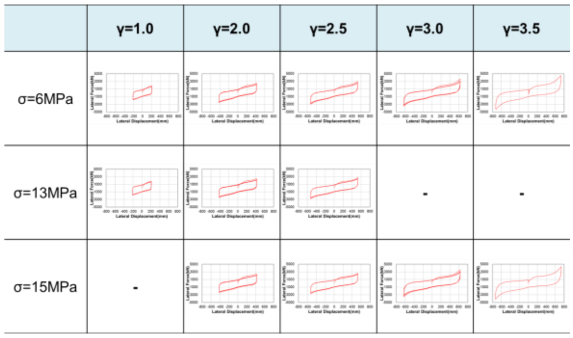

Fig. 6. Performance Diagram of Full-scale MLRB

4. Conclusions

In this paper, it was evaluated the performance testing in variable axial load & shear displacement with the full-scale multi-lead rubber bearing for the application of nuclear power plants.

From the test results, the design of bearing performed properly and appeared the excellent stability under the more than design value.

Therefore, this bearing will be have too enough features under high axial load and earthquake with the large relative displacement.

ACKNOWLEDGMENT

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