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Shear Performance Evaluation for Lead Rubber Bearings by Accelerated Aging Test

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1. Introduction

A study on application of the base isolation system to the sodium fast reactor (SFR) and pressurized-water reactor (PWR) has been recently performed. The behavior of base isolated NPPs is generally influenced by the behavior of base isolators. According to the ASCE-4 [1], it was required that the long-term behavior of base isolators should be evaluated because the safety of base isolated NPPs was ensured during the operation period. Although the rubber material in base isolators was used to ensure the restoring force, it was changed with time. The long-term behavior of rubber bearings such as lead rubber bearings (LRBs), natural rubber bearings (NRBs) and high damping rubber bearings (HDRs) was mainly affected by the aging of rubber.

In Japan, from the test results of Itoh [2] analyzed the influence factors on the aging of rubber material by aging test and the aging of rubber material was most affected by the oxidation. In USA, the property modification factors have been applied to consider the variation of seismic isolators due to aging at the design state.

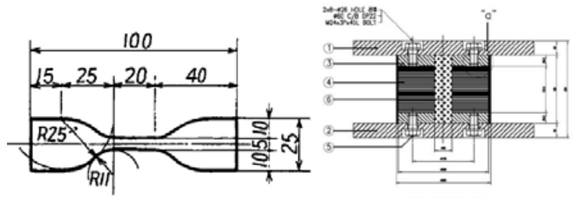
In this study, the accelerated aging test of rubber material was conducted to discover the mechanical properties on tensile, shear and adhesive of rubber by aging. In addition, the aging test of LRB was conducted to evaluate the shear performance of LRB.

2. Accelerated aging test

Accelerated aging tests are generally used for predicting the life of rubber products and investigating the properties of rubber products under ambient conditions. The test means the aging at constant temperatures and measuring mechanical properties of materials (such as hardness, tensile strength, elongation at break, shear strength, etc.).

Natural rubber samples were prepared with the shape of dumbbell specimens specified by ISO 22767-1 [3]. The thickness of specimens was 2 mm, and the width and length of middle part was 5 mm and 20 mm, respectively. 126 dumbbell specimens for aging test of rubber material as shown in fig 1 (a).

LRBs with diameter of 250 mm (D-250) were manufactured according to the ISO standard test piece [3]. Figure 1 (b) showed the test specimen of LRB.



(a) Dumbbell specimen (b) LRB specimen
Fig. 1. Test specimens for accelerated aging test

18 specimens were prepared for aging test of LRB. The properties test of rubber material was conducted according to the ISO 22767-1.

Test specimens were suspended in oven as shown in figure 2. The temperature were kept at three elevated temperatures, 70 ºC, 85 ºC, 100 ºC. For the test at each temperature, the aging time for dumbbell specimens were set as 14 stages (0, 1, 2, 4, 7, 14, 30, 45, 60, 75, 90, 120, 150, 180). The aging time and temperature of LRB were determined based on the Arrhenius equation calculated from the aging tests of dumbbell specimens.

The shear test of LRB was performed under cyclic loading with increasing the strain as shown in table 1. If the LRB under cyclic loading did not reach to the shear failure, the monotonic loading test was performed until the LRB was failure.

Fig. 2. Experimental setup for aging test of rubber

Table 1. Test plan for shear performance evaluation of LRB

Test item	Strain (%)	Frequency (Hz)	Cycles
Shear strain dependency	50%	0.1	3
	100%	0.1	3
	150%	0.1	3
	200%	0.1	3
	250%	0.1	3
	300%	0.1	3
	350%	0.1	3
Shear failure	500%	0.005	-

3. Accelerated aging test results of rubber material and LRBs (D-250)

3.1 Property test of rubber material

The properties of rubber material can be different with time. Therefore, it was required that the various mechanical properties of rubber material was evaluated with time.

The failure point should be defined to plot the Arrhenius curve. In this study, the failure point on hardness, tensile strength and elongation was assumed according to the EN 1337-3 [4].

The Arrhenius equation can be calculated by performing a linear regression analysis from relationship between the lifetime and temperature. From the Arrhenius plot of each properties, it was found that the hardness of rubber was a dominant property on the aging. Based on hardness, it was showed that the lifetime of rubber material was 64 years at 20 °C as shown in figure 3.

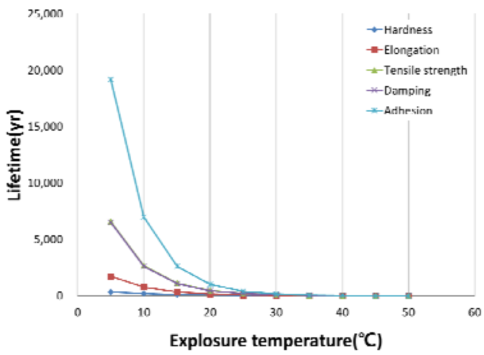


Fig. 3. Lifetime of rubber material at various temperature

3.2 Long term behavior of LRB by aging test

The shear test was performed to investigate the long-term behavior of LRBs. The shear force-strain curve obtained by the shear test was shown in figure 4.

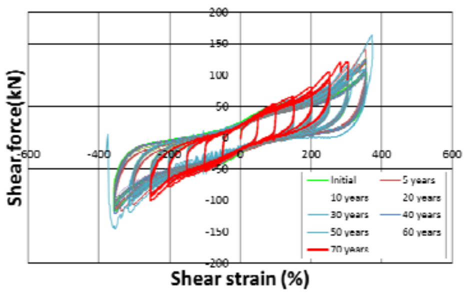


Fig. 4. Shear force and strain of LRBs with time

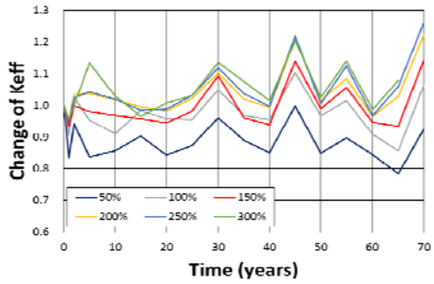


Fig. 5. The effective stiffness of LRBs with time

Although the test results included the variability in manufacturing process, it was showed that the horizontal stiffness of LRBs was increased with time. The change of horizontal stiffness was different by the shear strain because the nonlinear hardening effect at large strain occurred. The variability of horizontal stiffness of LRBs (D-250) was increased about 20% at 45 years as shown in figure 5.

4. Conclusion

The accelerated aging test was performed to investigate the mechanical properties of LRB with age-related degradation.

From the accelerated aging test of rubber material, it was presented that the hardness was the most important property on the aging of rubber. It was concluded that the lifetime of rubber material was 64 years at 20 °C. It was presented that the variation of horizontal stiffness of LRB was about 20% including the material variability in manufacturing and aging.

Considering the allowable variability of LRB and accelerated aging test results, the plan for replacement/maintenance of LRB can be established.

Acknowledgement

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