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Aging Depth Test of Rubber Blocks by Accelerated Thermal Oxidation Test

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1. Introduction

The mechanical properties of rubber bearings were changed with time. Because the aging effect of rubber material was generally higher than that of other structure materials it is needed that the aging properties of seismically isolators should be evaluated to ensure the safety of seismically isolated nuclear power plants (NPPs) over the lifetime. NRC [1] and ASCE [2] required the tests of seismically isolators for investigating the aging properties. JNES [3] also required the seismic response analysis for the seismically isolated NPPs when the properties of seismically isolators were extremely changed. If the aging properties of seismically isolators such as rubber bearings are evaluated by analysis the analytical model of seismically isolators should be developed considering aging effect of rubber material.

From the previous research [4], it was reported that the behavior of aged rubber material mainly affected by temperature and oxidation. The material properties between surface and inside can be different by the oxidation of rubber. Therefore, the aging depth should be investigated for exactly evaluating the seismic behavior of aged rubber bearing.

In this study, the accelerated thermal oxidation tests of rubber block were performed to investigate the aging depth of rubber bearing. From the tests, it was found the critical aging depth in rubber block. Also the property variation of rubber was investigated along the depth.

2. Aging depth test of rubber block

The aging depth test was performed according to the below procedure to analyze the deteriorated properties of rubber block from surface to inside.

2.1 Manufacture of rubber blocks

In this study, the rubber blocks were manufactured to easily investigate aging depth.

Before manufacturing the rubber block, the thickness, width and length were defined. The thickness was defined considering the aging depth predicted by previous research. The width was defined by the length of dumbbell specimens and the length was defined by the number of dumbbell specimens. In this study, the size of rubber block was equal to 385 mm × 190 mm × 95 mm as shown in Fig. 1.

After selecting the size of rubber block, the number of rubber block was defined by aging time. In this study, 11 rubber blocks were manufactured.

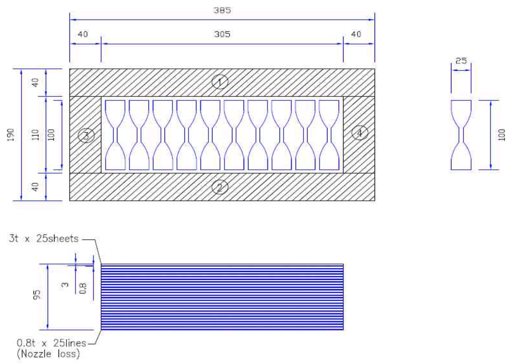


Fig. 1. Drawing of rubber block

2.2 Accelerated thermal oxidation test

Accelerated thermal oxidation test was performed under a temperature of 70 ℃ to deteriorate the rubber blocks. 10 rubber blocks were located in the heat chamber as shown in Fig. 2. The distance of each rubber blocks was to be 5 cm to minimize a temperature interaction between rubber blocks. The aging time was to be 472 days considering the lifespan of NPPs.

Fig. 2. Rubber block in heat chamber

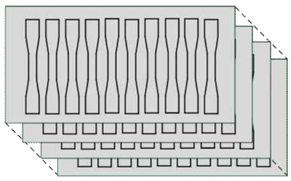


Fig. 3. Plan for cutting of rubber sheets

2.3 Test specimens and Property tests

The rubber sheets cut out from the deteriorated rubber blocks as shown in Fig. 3 to manufacture the dumbbell specimens. The rubber sheets cut along the thickness direction using a water-jet in this study to create a uniform section. The thickness of 2-3 mm for rubber sheets was defined considering a loss of thickness occurred by cutting process.

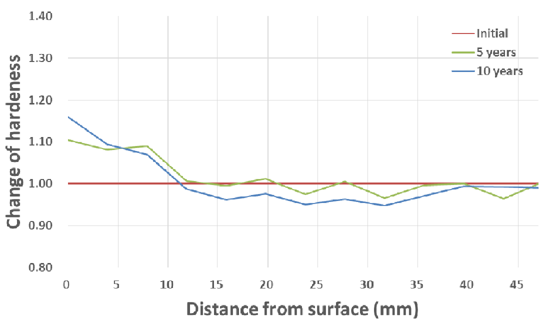
The rubber material is generally changed with time. So the property tests of aged rubber material were performed according to the time. In this study, a hardness and tensile tests were performed.

3. Test results

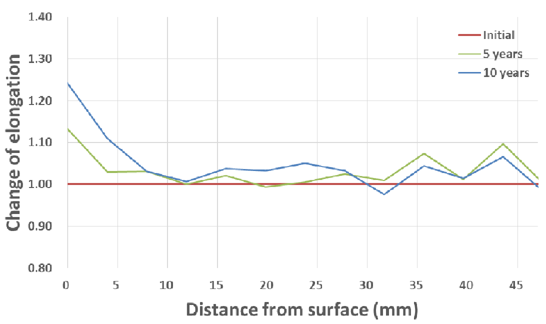
For investigating the deterioration pattern according to the depth, the property tests of rubber were performed at intervals of 2 mm along the thickness direction. Fig. 4 shows the test results of rubber material from surface to inside. The vertical axis means the property variation. The horizontal axis presents the depth from surface to the center of rubber block. Fig. 4 (a) shows the change of hardness with depth. From the test results, it was showed that the hardness at surface was greatly changed and the variation of hardness was sharply decreased with increasing depth. The hardness of surface was increased because a surface of rubber was exposed into atmospheric oxygen. While the hardness of inside was similar to initial state because an inside of rubber was blocked from an oxygen because of cover layer. If the distance from surface exceeded 10 mm the variation of property had converged at the unity that means, there is no aging at the depth.

From the tensile test, it was found that the tensile strength was increased and the elongation at failure was decreased with time. The deterioration pattern by tensile test was similar to that of hardness test result as shown in Fig 4.

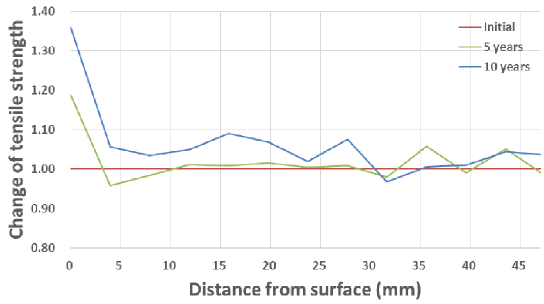
The property variation at surface of rubber block was increased with time. While the critical aging depth not affected by aging time.



(a) Hardness



(b) Elongation



(c) Tensile strength

Fig. 4. Properties profile

4. Conclusion

The deterioration pattern from the aging depth tests was found from surface to inside and the critical aging depth was to be about 10 mm.

The analytical model for rubber bearing with aging can be developed based on the relationship between the property variation and aging depth investigated from this study.

The aging depth of rubber baring was not influenced by the size of seismically isolators but environment condition. Therefore, the detail analysis considering aging depth was not required for NPPs with large seismically isolators. But the seismic response analysis for NPPs with small seismically isolators should be performed in detail considering the aging. In this case, the results of this study can be used for developing the aging model of rubber bearings.

Acknowledgement

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REFERENCES

[1] U.S. Nuclear Regulatory Commission (USNRC), "Technical Considerations for Seismic Isolation of Nuclear Facilities (draft)," NUREG-draft, 2011.

[2] American Society of Civil Engineers (ASCE), "Seismic Analysis of Safety-Related Nuclear Structures, ASCE-4, Reston, VA, 2013.

[3] Japan Nuclear Energy Safety Organization (JNES), "Technical Review Guidelines for Structures with Seismic Isolation (draft)," 2012.

[4] Gu, H., Itoh, Y, "Aging Behavior of Natural Rubber in Isolation Bearings," Advanced Materials Research, Vol. 163, pp. 163-167, 2011.