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Mechanical Property Test of Natural Rubber Bearing for the Evaluation of Uncertainty Value of Seismic Isolation Devices

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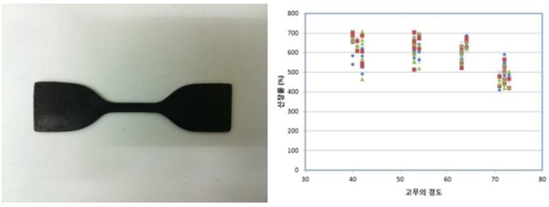
1. Introduction

Seismic safety of NPP is one of the most important issues in a nuclear field after great east Japan earthquake in 2011. For the improvement of seismic safety of nuclear power plant, seismic isolation is the easiest solution for increasing the seismic safety. Otherwise, the application of seismic isolation devices for nuclear power plants doesn't make the seismic risk of NPP increases always. The rubber bearing have many uncertainties of material properties and large displacement should absorb according to the application of isolation devices.

In this study, for the evaluation of uncertainty of the material properties of rubber bearing, material tests for rubber and mechanical properties test for natural rubber bearing were performed. For the evaluation of effect of hardness of rubber, 4 kinds of rubber hardness for material property tests and 2 kinds of rubber hardness for mechanical property test were considered. As a result, the variation of material properties is higher than that of mechanical properties of natural rubber bearings.

2. Rubber Material Test

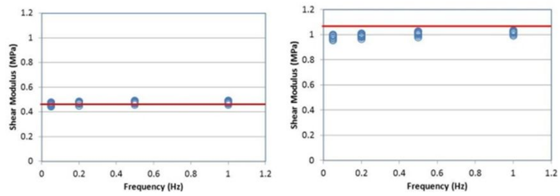
For the evaluation of material properties of rubber, normal and shear strains were determined. For the performing a normal strain test, standard specimen which defines by ISO was used. The shape of a test specimen and the test results are shown in Figure 1. As shown in Figure 1 (b), the elongation ratio of rubber material has pretty much diversity.



(a) test specimen (b) elongation ratio
Figure 1. normal train test for rubber material

For the performing a shear strain test, test specimens were manufactured according to the ISO standard. The four block type test specimens were selected for shear strain test. One of the test specimens is shown in Figure 2. Frequency dependences of shear strain for rubber material according to hardness are shown in Figure 3. As shown in Figure 3, the shear strain of rubber material is not much differences according to the test frequency.

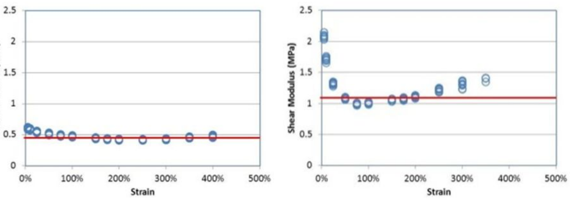
Figure 2. Test model for determining shear strain of rubber material



(a) 40 (b) 60
Figure 3. Frequency dependences of shear strain for rubber material according to hardness

Displacement dependences of shear strain for rubber material according to hardness are shown in Figure 4. The red line indicates a design strain. As shown in Figure 4, the shear strains have much uncertainty according to the test displacement and hardness. In the case of hardness 60 specimens, the shear modulus of small displacement range is almost twice of design strain. In this case, the stiffness of rubber bearing might be largely changed according to the input seismic motion.

Hysteresis of rubber materials according to displacement dependences are shown in Figure 5.



(a) 40 (b) 60
Figure 4. Displacement dependences of shear strain for rubber material according to hardness

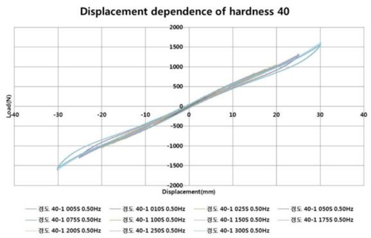


Figure 5. Hysteresis of rubber materials according to displacement dependences

3. Mechanical Property Test for Natural Rubber Bearing

For the performing of developing mechanical properties of rubber bearing, mechanical property tests were performed. The hardness level of rubber bearings are selected as 40 and 60. Three rubber bearings of the each hardness are manufactured. The rubber isolators for mechanical property test are shown in Figure 6. For the assessment of vertical stiffness variation, vertical stiffness tests were performed. The test results are shown in Figure 7.

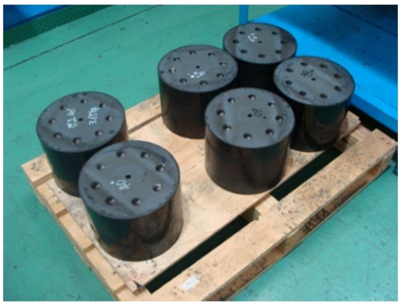
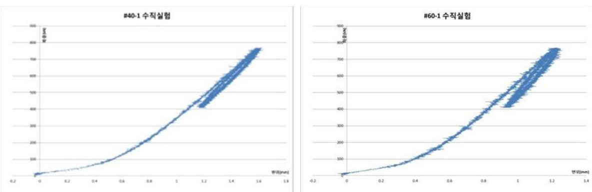


Figure 6. Natural rubber bearing for mechanical property test



(a) 40 (b) 60

Figure 7. Vertical stiffness test results according to hardness

The test results of displacement and frequency dependent horizontal stiffness according to the hardness of rubber are shown in Figure 8 and 9, respectively. The red lines are indicates design stiffness of rubber bearing. As shown in Figure 8 and 9, some experimental results are large differences between design value and experimental results. Especially, the frequency dependent stiffness results have almost 20% differences between design and experiments. The experimental results of ultimate capacity for natural rubber bearing are shown in Figure 9. As shown in Figure 8, the strains are linearly increased almost 200% strain level and after that the hardening effect occurred.

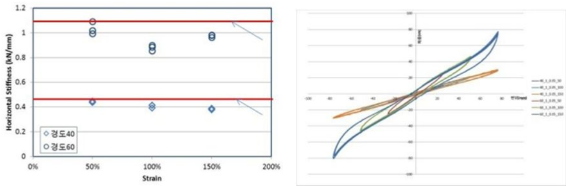


Figure 8. Displace dependency results of natural rubber bearings.

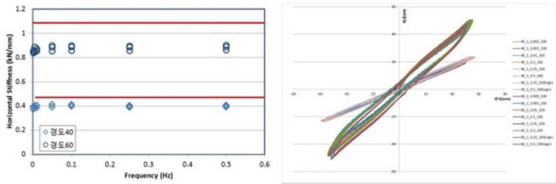


Figure 8. Frequency dependency results of natural rubber bearings.

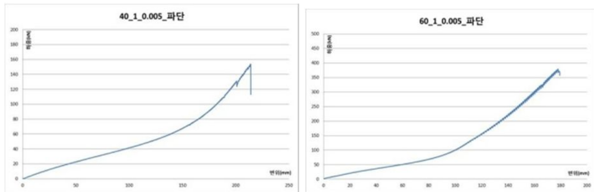


Figure 9. Ultimate capacity test results of natural rubber bearings.

4. Conclusions

In this study, mechanical properties of rubber materials and natural rubber bearings are determined by experimental work. The normal and shear strains of rubber materials are determined. The vertical stiffness and horizontal stiffness of natural rubber bearings are determined by mechanical property test and finally the ultimate capacity was determined by fracture test.

Through this test the uncertainty value of rubber bearing can be estimated. The quality of rubber bearing for nuclear power plants is one of very important point for the safety of nuclear power plants. The results of this experiment can be applied to the determination of capacity criteria seismic isolation system.

ACKNOWLEDGEMENT

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REFERENCES

[1] ISO22762-1, International Standard, Elastomeric seismic-protection isolators –Part 1: Test methods